A STUDY OF THE EFFECTS OF LONG-TERM GROUND AND FLIGHT ENVIRONMENT EXPOSURE ON THE BEHAVIOR OF GRAPHITE-EPOXY SPOILERS

By Robert L. Stoecklin

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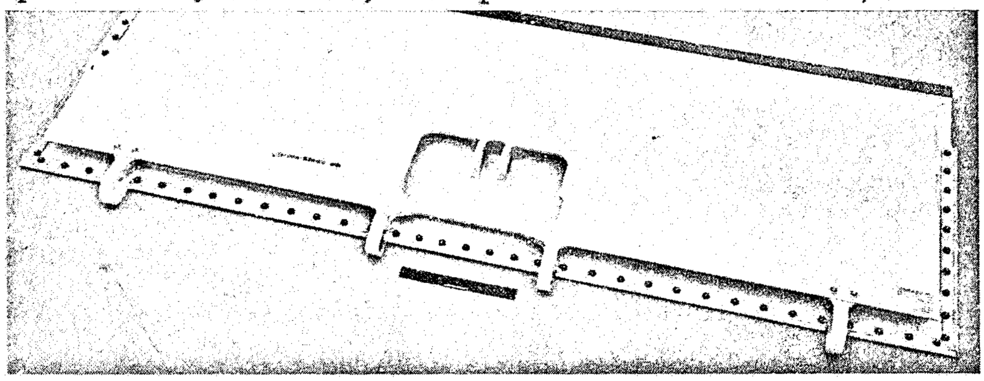

Third Quarterly Progress Report
D6-60170-3
April 1973

Prepared under contract NAS1-11668 by
BOEING COMMERCIAL AIRPLANE COMPANY
P.O. Box 3707
Seattle, Washington 98124

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16. Abstract

This quarterly report is prepared in compliance with the requirements of contract NAS1-11668 and covers the work performed from January 1, 1973 through March 31, 1973. Task I of this contract is in progress and consists of procurement and production activities required to implement the production run of 114 Boeing-designed graphite flight spoilers for the 737 airplane. The task II effort, which will include design and fabrication of an advanced-design, all-composite spoiler, is also under way. Flight spoilers from both task I and task II will be flown on commercial 737s for a period of 5 years to gather data on the environmental durability of graphite-epoxy material systems.

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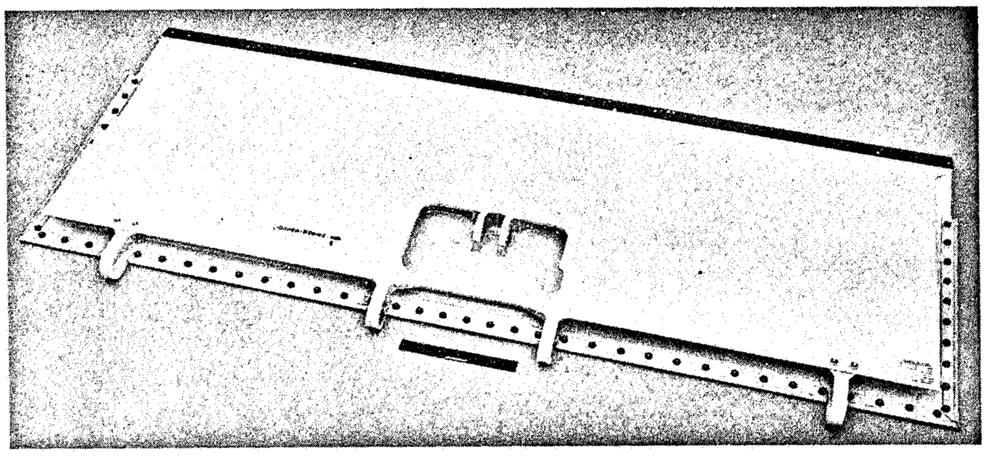

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CONTENTS

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By Robert L. Stoecklin
Boeing Commercial Airplane Company

SUMMARY AND PROGRAM STATUS

This third quarter progress report is submitted in accordance with the requirements of contract NAS1-11668 and covers the work performed during the period from January 1, 1973 to March 31, 1973.

The objective of this program is to produce 114 task I and eleven task II 737 flight spoilers for laboratory testing and service evaluation deployment. Four task I spoilers will be installed on each of 27 aircraft representing five major airlines operating in different environmental circumstances. These units will be monitored under actual load and environmental conditions for a period of 5 years. Periodic removal of selected units will be accomplished to evaluate any material degradation as a function of time. Task II spoilers will be phased into the evaluation program as additional installations as well as replacements for task I spoilers removed for evaluation and testing.

The third quarter activities have been devoted principally to implementing production of the task I spoilers. These activities include fabrication of in-house detail components and completion of assembly of the initial scheduled spoiler units. The initial spoiler was completed on February 13, with the production of subsequent units achieving a one-per-day rate by the end of the quarter. Initial production start-up problems have been met and resolved.

Production of detail components and procurement of vendor-fabricated details have satisfactorily supported the assembly process. Present projections are that production will be completed as scheduled.

Fabrication and static testing of the three test spoilers have been successfully completed during this report period. Strength and stiffness results obtained were exceptionally favorable. Weights reporting to date has also been favorable.

Considerable progress has been made in coordination of activities both with the FAA toward type certification and with the participating airlines toward agreements regarding deployment of 737s. Both of these areas will be resolved completely in the upcoming quarter.

For the task II advanced-design spoilers, the preliminary investigations into the potential configurations of the integrated composite hinge and spar components are continuing. At least two separate approaches will be available for final evaluation.

DESIGN

MATERIAL SCREENING

The following is a summary of the events and results of cure cycle application in both the material screening program and the production effort in the current reporting quarter. In all cases the cure cycles recommended by the graphite prepreg suppliers required modification to obtain the laminate characteristics set forth in the engineering requirements.

Union Carbide (Thornel 300/2544)

Screening.—Union Carbide's recommended cure cycle was used and the laminates were found to be high in fiber volume. Union Carbide stated that this could be controlled by bleeder ply configuration in spoiler skin production. The schedule did not allow further investigation in the screening program.

Production.—Preproduction test panels, when cured per Union Carbide's cure cycle, were again found to be high in fiber volume. Test values met specification requirements, but fibers peeled easily from the laminate surface. Discussions were held with Union Carbide via telephone to obtain curing characteristics such as gel time, viscosity change vs temperature, etc. Union Carbide then verbally revised their cure cycle to accommodate production conditions such as slow heat-up rate and pressurization rate in the autoclave. Using revision A cycle, the first four production skins bled excessively and individual plies peeled easily from the laminate. The excessive bleedout was not as apparent in small test panels as it was in full production skins. Union Carbide technical people were called for on-site discussion and problem resolution.

Using gel information obtained in laboratory tests, it was deduced that pressure application at temperatures below 250°F will, in fact, yield high fiber volume fraction laminates. Union Carbide did not agree but, upon witnessing gel tests in the Boeing Materials Laboratory, they concurred that there was something not correlating between Boeing and Union Carbide. Using Boeing gel data a cycle was devised in which pressure was applied at 270 F. The resulting laminate measured approximately 60% volume fraction with 0% voids. This is the cycle presently being used in production (fig. 1).

Union Carbide subsequently discovered that their gel point apparatus was reading 25 F lower than actual gel temperature and, with gel times corrected, their readings correlated with Boeing data.

Narmco (5209/Type A-S, 5209/Thornel 300)

Screening.—Narmco's cure cycle and bleeder recommendations were followed in the screening process, and volume fraction of 60% with 0% voids was obtained with 5209/type A-S fiber (Hercules). It was felt that their system, as described by Whittaker, was very sensitive to peel ply and bleeder ply configuration.

Production.—Whittaker requested they be allowed to change from type A-S fiber to Thornel 300, for their production quantities, for reasons of cost savings. They stated that there would not be any change in other processing or resulting properties.

Receiving inspection panels were layed up and cured in the Auburn facility. It was noted that the resin bleed was excessive and removal of the peel ply pulled some fibers from the laminate surface, thus indicating an extremely high fiber volume fraction. Fiber-volume tests were performed on the panels, and the fiber content was found to be in the range of 68%-70%. Whittaker was contacted to discuss what they would recommend as a change to their cure cycle to reduce the volume fraction to 60 ± 2%. Whittaker recommended a longer hold at 175°F (up to 30 minutes) followed by the usual procedure. Using this cure cycle, the fiber volume was not reduced.

A series of gel times vs temperatures were taken and plotted. These showed that the gel time was long and not very well defined at temperatures below 225°F. Between 225°F and 250°F, the gel point was well defined. A cure cycle revision was adopted in which pressure was applied beginning at 235°F and, when part temperature reached 250°F, the temperature was held until 100 psi positive pressure was reached. Pressure was then maintained for 90 minutes. Using this cure, volume fraction ran 58%-60%. Laminates, cured using both cycles, were tested and except for tensile ultimate, the properties were essentially the same, except that the fibers did not peel with the lower fiber volume fraction laminates.

Whittaker has indicated that 5209/Thornel 300 will be optimum at fiber volume fraction of 68%-72%, but Boeing feels this is not substantiated by test, and will therefore target skins at 60 ± 2% using the revised cycle (fig. 2).

Hercules (3501/Type A-S)

Screening.—Hercules recommended a straight heat-up rate to 350°F with no dwell and applying pressure at 280°F. Laminates tested showed a fiber volume of 54% with average mechanical properties. The quality of the prepreg was, however, very poor and the laminates exhibited a "washboard" condition which most likely had some adverse effect on the mechanical properties.

Production.—The first production run of Hercules material was rejected because of poor prepreg quality. The following production shipment was used for eight skins, but poor prepreg quality resulted in rejection of the balance of the shipment. However, a portion of this material was used to optimize the 3501 cure cycle. Using the Hercules cure cycle, fiber volume was low, indicating late application of pressure. Gel tests were made on the 3501 system which indicated that pressure should be applied prior to 275°F. It was found that applying pressure too early resulted in an increase in voids and not necessarily an increase in fiber volume. This was confirmed in discussions with Hercules technicians. Plotting specific gravity against fiber volume and comparing to optimum specific gravity at various fiber volumes, it was difficult to obtain a specific gravity corresponding to 58%; that is, the specific gravity was always low or off the optimum line. Another cure cycle was devised wherein full vacuum was applied while heating to 225°F. As heating continued to 250°F, pressure was increased to full molding pressure. This cycle yielded laminates having a volume fraction of 59%-61% at almost optimum specific gravity. However, it is felt that the 3501 systems, when cured via autoclave, will give laminates having 0.5%-5.0% voids.

A production test panel was fabricated, using the revised cure cycle (fig. 3), from 10 lb of evaluation prepreg material, and the resulting laminates had a volume fraction of about 62%.

QUALITY CONTROL

The Quality Control research and development effort for this reporting period has been devoted to effecting the transition of nondestructive testing quality surveillance to production shop personnel. Quality Control R&D personnel will maintain a surveillance and consultation responsibility over the continuing NDT effort.

The following efforts have been completed in this period:

- Complete NDT inspection of 18 spoiler units
- Destructive evaluation of portions of static test spoiler S/N 0002
- Destructive evaluation of portions of static test spoiler S/N 0081
- Development work on an improved C-scan color standard

The Quality Control C-scan ultrasonic through-transmission facility was undergoing repairs between February 12 and March 18. During this period a smaller laboratory scanner was transferred to the Auburn production area and will be maintained exclusively for the spoiler program. During this period of inoperability, the first two static test units (S/N 0002 and 0041) were run using a black-and-white recording only, since the static test articles would not require future reference to color recordings. Color recordings were begun with the third unit and included the third static test article (S/N 0081).

C-scan records will be filed with the production planning paper for comparison with future recordings to be made following flight service evaluation.

To date, six color recordings of the 18 spoilers which have undergone NDT inspection have displayed areas of high ultrasonic attenuation relative to the surrounding panel area. High ultrasonic attenuations are generally observed in the region immediately aft of the center hinge fitting and around the -11 doubler periphery. Occasional high attenuation areas have also been noted on the sides of the panels adjacent to the fiberglass end ribs.

To interpret the significance of the relationship of ultrasonic transmission through the panel to actual structure, the left side of static test panel 65-76327-3 S/N 0081 was cut into three pieces (following completion of the static test) and all pieces chemically milled to remove the aluminum structural elements. The results of this effort are shown in figures 4 through 8. Figure 4 shows the overall view of the three pieces as they relate to the total structure. Figures 5, 6, and 7 show the detail in the leading edge piece. Note the excellent filleting of the film and core splice adhesive. The "strings" are node bond adhesive contained in the aluminum honeycomb core as supplied from the vendor. Notice also the honeycomb repaired area in figure 5 (patch of potting compound) near the leading edge. This patch was seen as a highly attenuated ultrasonic signal in the C-scan recording. Figure 8 shows the transition section adhesive filleting. The remainder of the panel is being evaluated by radiography and will also be destructively tested by chemical milling.

Following static test, 65-76327-1 S/N 0002 was also destructively evaluated by quality control inspection personnel. Attempts to mechanically remove the upper and lower skins from the honeycomb core resulted in complete destruction of the core. The skin laminates invariably would delaminate before failure of either the honeycomb-to-laminate bondline or the laminate-to-edge member bondline. Adhesive bonding was termed excellent. No further destructive examinations are planned by Quality Control.

An improved color standard is being developed for greater accuracy in cross-panel comparisons. Consisting of a 10-step machined polyurethane plastic block which exactly attenuates the ultrasonic signal at the midrange decibel values, this standard will become part of each color C-scan record when development of the procedure is complete. At present, ultrasonic indications on any given recording must be compared to the background attenuation level for each respective panel only. Small differences which exist between background levels of different panels preclude precise cross-panel comparisons. Such comparisons must be made on a relative basis.

As an additional assurance of uniform pressure application throughout the bonding tools, several verifilm profiles were obtained on early production units. Verifilm is a specific term for the adhesive flow pattern obtained when the normal tape adhesive has been treated for nonadhesion and the spoiler is "bonded" per specifications. The treated, cured film is withdrawn from the bonded assembly for each bondline.

Verifilm patterns of the first two panels indicated porosity and voids under the center hinge fitting to the -11 doubler bondline. These defects were not seen after the doubler was reworked to include vent holes.

Verifilm also revealed low pressure patterns on the lower skin-to-honeycomb bondline believed to be due to bent-over cell wall edges or excessively machined core. These same patterns were seen as high attenuation areas on the ultrasonic C-scan.

ENGINEERING DESIGN

With the task I design effort virtually completed, the engineering effort has become fundamentally a production liaison function to oversee the orderly progression of production activities and events.

One significant development during this quarter has been the assembly of a significant quantity of weights data to measure the effectiveness of utilizing graphite materials. Program planning calls for collection of actual weights on each production unit. Additional data have been collected on early production units prior to installation of seals and application of surface coatings and finishes. Table I shows the data collected to date together with the corresponding values for the current 737 aluminum flight spoiler. A preliminary assessment of the heavier weight values associated with Narmco (65-76327-2) spoilers indicates the possibility that ply thicknesses are running heavier than the 5.5-mil nominal value. Investigation of this subject is continuing.

It appears that significant weight reductions will be demonstrated on the program, with the possibility of differences among the three prepreg suppliers being detectable.

Minor repair techniques are being attempted on selected discrepant spoiler units. The selection criteria are based on the severity and location of the damage to be repaired. In general, repairs will be attempted on those spoiler locations shown in static test to be lightly loaded or on more highly stressed areas where substantial margins of safety exist.

An example of such a repair is shown in the case of spoiler S/N 0005. While in the paint shop for conductive coating and enamel finish, the spoiler was accidentally damaged when a transportation cart struck the hanging spoiler on the left trailing edge corner, damaging the upper skin (-8) and the end rib (65-76301-1) and causing a delamination of the trailing edge joint for a distance of 2 in. along the trailing edge (figs. 9 and 10).

With a knowledge of the low pressure loadings near the trailing edge, a repair technique was devised which would preserve the integrity of the upper graphite skin and utilize the strength of the fiberglass end rib to preclude future delamination failure of the graphite. This was accomplished by trimming away the failed portion of the end rib flange and repairing with a fiberglass patch, keeping an end overlap of 0.50 in. to develop the strength of the repair patch.

The trailing edge delamination was repaired by injecting BAC 5010 type 38 adhesive into the void, clamping the surfaces to re-establish a straight line trailing edge, and curing at 120°F for 2 hours.

After repair (figs. 11 and 12), the spoiler was returned to production for final finish processes.

PROCUREMENT

GRAPHITE MATERIAL

Procurement of the prepreg graphite tape material has accelerated during the current quarter. Incremental deliveries of tape have been received from each of the three suppliers and channeled

TABLE I.—SPOILER WEIGHT TABULATION

Spoiler production sequence number	Spoiler serial number	Graphite tape supplier	Unpainted weight (lb)	Completed weight (lb)
737 production	65-46451		14.10	15.38
1	0001	Union Carbide	11.43	12.75
2	0002	Union Carbide	11.40	(a)
3	0041	Narmco	12.38	(a)
4	0003	Union Carbide	11.84	13.12
5	0004	Union Carbide	11.43	12.48
6	0005	Union Carbide	11.30	(b)
7	0006	Union Carbide	11.32	12.52
8	0007	Union Carbide	–	12.60
9	0042	Narmco	–	13.50
10	0081	Hercules	11.77	(a)
11	0008	Union Carbide	–	12.70
12	0009	Union Carbide	–	12.61
13	0010	Union Carbide	–	12.81
14	0043	Narmco	–	(b)
15	0044	Narmco	–	(b)
16	0045	Narmco	–	(b)
17	0046	Narmco	–	(b)
18	0011	Union Carbide	–	(b)
19	0015	Union Carbide	–	(b)
20	0014	Union Carbide	–	(b)
21	0016	Union Carbide	–	(b)
22	0013	Union Carbide	–	(b)
23	0012	Union Carbide	–	(b)
24	0017	Union Carbide	–	(b)
25	0083	Hercules	–	(b)
26	0082	Hercules	–	(b)

[a]Static test article—no painting or seals used
[b]Incomplete at report time

into the production facilities. As a consequence of the stringent graphite tape requirements established by Engineering for this program, a variation of fabrication experience has resulted with regard to graphite skin layups.

The first supplier (Union Carbide) has delivered a total of 113 lb of Thornel 300/2544 tape in three separate shipments. Physical appearance and compliance with program requirements have been consistently good. Laminate properties have consistently been above requirements. To date approximately 59% of the skin units fabricated have been laid up with Union Carbide tape.

The second supplier (Narmco) has delivered a total of 132 lb of material, with 87 lb arriving as the quarter ended. Physical appearance of the Thornel 300/5209 prepreg has been relatively good, but difficulties have been experienced with the backing paper and secondary difficulties have been experienced with prepreg physical characteristics. Narmco has actively pursued both problems and in the case of the recently arrived shipment of 87 lb, most, if not all, of these problems appear to have been solved. To date approximately 23% of the skin units fabricated have been laid up with Narmco tape, with skins being laid up with Narmco material as the quarter ended.

The third supplier (Hercules) has delivered a total of 112 lb of 3501/AS prepreg tape in three shipments. The first shipment of 53.2 lb was returned to Hercules under an Engineering rejection for tape quality. The second shipment of 47.7 lb was used to make eight skin units, and the balance is currently under an Engineering rejection for tape quality. The third shipment (11.24 lb) was submitted by Hercules for evaluation of improvement in tape quality. Four -10 skins were laid up and cured, but are currently under an Engineering rejection awaiting resolution of mechanical property evaluations by both Hercules and Boeing. Approximately 18% of the skin units fabricated to date have been laid up with Hercules tape.

Considerable effort has been expended on this program to obtain prepreg tape quality measurably better than that available from the industry prior to implementation of this program. The need for improved tape quality to permit the use of automatic tape-laying equipment has been satisfactorily demonstrated. Continued insistence on the established level of tape quality will be beneficial to future composite production programs.

METAL DETAILS

Procurement of the metal production details from the 737 subcontractor has proceeded on schedule. To date a total of 74 sets of metal details, including the center hinge fitting (P/N 65-49507-8) have been procured and are in production stores. The shipment schedule established in the preceding quarter with the 737 subcontractor has been consistently met, and no delays in spoiler production have been encountered due to lack of center hinge fittings. Deliveries of fittings and other details are proceeding at a rate of five per week, with the final shipment scheduled for June 1.

PRODUCTION

SPOILER FABRICATION

Production activities have experienced a dramatic increase in tempo in the past quarter. At the beginning of the quarter, components for the first spoiler unit were progressing through the assembly stages. Scheduled completion date for this unit was February 8. Toward the end of the quarter, components were moving through the assembly sequence (fig. 13) at a rate of one unit per day. At the end of the quarter, 13 completed units had passed final inspection. Those units scheduled for static test had been routed to the Structures Laboratory, while the remaining units were packaged into shipping containers, awaiting delivery orders to the several participating airlines. In addition to the 13 completed units, additional numbers of partially completed spoilers were in the fabrication process. Figure 14 shows the status of production components as of March 31.

The number of completed spoiler units has not matched the scheduled completion curve (fig. 30). Several problems associated with the start-up of production account for this difference. Among these problems were:

- Inability of bond assembly jig to maintain -4 honeycomb assembly in position prior to second-state bonding of graphite skins
- Inability of bond assembly jig to maintain graphite skins in proper position during bonding operation
- Mechanical malfunction of multilevel color C-scan equipment, which delayed NDT operations for a period of 4 weeks (periodic verifilm operations were utilized as an assist during this period)
- Engineering error in end rib design, which necessitated tool rework and scrappage of initial production of end ribs.

To facilitate a recovery schedule, the production rate must necessarily increase to a value greater than one unit per day. This would require that the second-stage bond operation (including its associated layup operation) must be performed more than once per day. During a trial period the last week of March, the final assembly bonding shop demonstrated this ability to load and cure second-stage bonds twice during a 24-hour period by utilizing a second shift. This capability is a key element in the bond shop's ability to support a recovery schedule which would be needed to return the production process to its original completion schedule.

The first production unit (S/N 0001) progressed through the fabrication process to the final assembly phase, where a shop error (skin trim between the center hinge fitting lugs) caused rejection of the unit. Engineering disposition of the unit consisted of painting only one-half of the spoiler, installing all seals and other details, and forwarding the spoiler to NASA-Langley as a display model (fig. 15).

Since program requirements dictate that all spoilers are to carry unique identification via serial numbers, the system of serial number assignment shown in table II will be utilized for task I identification.

TABLE II.—SERIALIZATION SCHEDULE

Graphite tape supplier	Spoiler part number	Serial numbers assigned
Union Carbide	65-76327-1	0001–0040
Narmco	65-76327-2	0041–0080
Hercules	65-76327-3	0081–0120

To stabilize the honeycomb core of the -4 assembly prior to bonding of the graphite skins, a film of EA 9628 adhesive is laid up on the flat surface of the unmachined honeycomb core and cured. This allows the machining operation to be performed without distorting the honeycomb cells. An additional advantage is that the stabilizing adhesive becomes a normal part of the second-stage bond assembly when an additional film of EA 9628 is applied to bond the graphite skins to the -4 honeycomb assembly.

The -4 assembly was modified with the addition of the -11 metal doubler, rather than installing the -11 doubler during the second-stage bond. This change allowed a more positive positioning of the -11 doubler plus additional honeycomb core stabilization for machining of the core.

Another contractual requirement for this program was the establishment of an "accountability log." This log is intended to contain the production records relating to each individual spoiler unit so that future events in the environmental exposure portion of the program may be referred back to the production records for explanation and/or problem solutions. Since the production planning paper will carry all of the detailed production information for each individual spoiler unit, plus the paperwork relating to special handling or repairs associated with a particular spoiler, the planning paper itself will be preserved by the program manager as the accountability log, together with any special paper (such as NDT records) which will permit a review of each spoiler's fabrication history and/or physical status at time of delivery to the participating airline.

GRAPHITE SKIN FABRICATION

At the beginning of the quarter, Auburn had completed the initial layup of four -8 upper skins made with Union Carbide tape. The laminates were rejected because they did not release from the layup mandrel properly and because the resin bled from them during cure was excessive. A revision to the cure cycle was developed by Engineering, and a test run was made to ensure that the parts would release from the tool if the resin content was correct and the release agent coating on the tool was adequate. The next set of four -5 lower skins proved to be acceptable to Engineering.

The next, and most significant problem to date in the program, appeared when attempts were made to use the Hercules production graphite tape (as opposed to the evaluation sample) for skin layups. Gaps and width variations far in excess of our specified allowances were numerous and random throughout the shipment. Approximately 100 ft of tape was removed from each of several reels. Engineering inspection indicated that the material was not acceptable, and the decision was made to return it to the vendor. Figures 16 and 17 are representative of these variations.

Next, skin layups were attempted with the initial shipment of Narmco tape. This tape also showed out-of-tolerance gaps and width variations, but to a lesser extent than the Hercules tape. The tape also had shreds of paper left on the carrier paper edges as a result of the slitting operation. The shreds had to be hand removed from between the edges of the laid tape strands to prevent their inclusion in the laminate. The problem was relayed to the vendor for solution.

A manufacturing representative was dispatched to the Hercules and Narmco plants to show them the unacceptable defects, explore the reasons for them, and assess the probability of resolution of the problems. Both vendors assured the representative that they could and would meet Boeing requirements. Tape subsequently received from Narmco was considered by the shop personnel to be the best received from any source to date. Several layups were made by machine without requiring any significant repair for gap or overlap. Solutions to the quality problems associated with the Hercules material are still being explored.

SPOILER TESTING

Upon completion of the static test specimens (spoiler serial numbers 0002, 0041, and 0081) the static test program was implemented. This program consisted of an application of the critical design pressure loads at blowdown (see fig. 4, p. 15, Second Quarterly Report) with the loading increased above design limit load until failure of the specimen. The data taken include applied airload and six deflection gages arranged on the spoiler periphery as shown in figure 18.

All three test specimens exceeded the ultimate strength of the 737 production aluminum spoiler and either equalled or exceeded the stiffness of the 737 spoiler measured at the trailing edge corners. Test data comparing the stiffness characteristics of the test spoilers with the 737 production spoiler are shown in figures 19, 20, and 21. The strength comparisons are shown in Table III.

Figure 22 shows a test spoiler in the test fixture. Figures 23 through 28 show the failed specimens. Figure 29 shows the 737 production spoiler deflected under 100% of limit load in the 1969 test program.

Testing was conducted from March 22 through March 28 and is documented in Boeing test report T6-5748.

FAA CERTIFICATION

Contact has been maintained with the FAA Northwest Regional Office, with the principal effort being aimed at briefing the FAA representatives on details of the previous spoiler certification obtained on the Boeing R&D spoilers (now in service with Western Airlines) and supplying static test data on the three test specimens. It was possible to schedule the third static test to permit an FAA Regional Office representative to observe the complete test.

TABLE III.—TEST SPOILER STRENGTH COMPARISONS

Test specimen	Ultimate strength (% design limit load)	Ultimate strength requirement, FAR 25 (% design limit load)	Failure description
65-76327-1 Serial number 0002 Union Carbide Thornel 300/2544	246	150	Failure of -11 aluminum upper surface doubler; yielding of 65-49507-8 fitting; secondary tensile failure of -8 graphite skin above -11 failure.
65-76327-2 Serial number 0041 Narmco 5209/Thornel 300	289	150	Failure of 65-49507-8 fitting, followed by shear failure of -11 aluminum doubler; secondary tensile failure of -9 graphite skin above fitting failure.
65-76327-3 Serial number 0081 Hercules 3501/type A-S	241	150	Compression failure of -7 graphite skin along aft edge of 65-49507-8 fitting; secondary failure of honeycomb core and lower skin along spoiler centerline.
65-46451- 737 production aluminum	210	150	Failure of upper surface skin in tension above 65-49507-8 fitting.

Successful completion of the static test program has cleared the way for a structural review by the FAA Regional Office. Upon completion of the Structures Laboratory report, a formal request for type certification will be made, accompanied by the test data substantiation. The highly successful test program will provide strong support for the certification request.

AIRLINE COORDINATION

Following receipt of the airline responses, which indicated willingness to participate in the NASA program with the numbers of aircraft proposed (First Quarterly Report, table 4, page 12), the Contract Administration personnel began preparation of a form agreement to be used as a negotiating base with each of the participating airlines. While each airline has agreed to the broader terms of participation in the program, detail agreements must necessarily be executed with each party as a firm basis for conducting the environmental test portion of the program.

It is anticipated that the first ship-sets of spoilers will be ready for delivery to the airlines during June 1973. It will be necessary to conclude these agreements prior to June 1 if this delivery schedule is to be met.

GENERAL

PROGRAM SCHEDULE AND PROGRESS

Progress of the program during the current quarter has been considerable, although the level of accomplishment anticipated on the production schedule (fig. 30) has not been achieved. At the end of the quarter the schedule indicated 29 units complete, while the status report (fig. 14) indicates 13 units actually complete.

Several factors are responsible for the failure to achieve the scheduled completion level. While it was considered highly desirable to achieve an "on-schedule" progress level, program management felt a greater responsibility to produce the highest quality units with the lowest possible risk toward eventual rejection of completed units for quality reasons.

Having achieved a lower production rate than originally scheduled does not necessarily mean that the original schedule cannot be recovered. As was stated in the "Production" section, the key production element of second-stage bonding has been demonstrated capable of processing bonded assemblies at twice the normal production rate (two units per day).

The factors which have held down production during this quarter were:

- Inability of the second-stage bonding tool to properly position the frame assembly prior to skin bonding (tool reworked)
- Inability of the second-stage bonding tool to properly position the skins prior to bonding (tool reworked)
- Engineering error in the detail design of the fiberglass end ribs (design changed)
- Mechanical malfunction of the multilevel color C-scan equipment, delaying production of subsequent units until the early test unit quality could be established (equipment now in service)
- Lower production rate of graphite skins due to prepreg tape quality problems.

Program management took the position that it would be prudent to resolve each problem which affected spoiler quality before producing additional units which could subsequently have similar quality problems. Where product quality and schedule conflicted, schedule was required to give way.

At the end of the quarter, all of the problem areas have been successfully resolved except for the prepreg tape problems. These are discussed elsewhere under "Materials."

It is anticipated that, barring unforeseen developments, the coming quarter will show a significant improvement in production rate, with a goal of recovering to the original production schedule by June 30.

Figure 31, the program schedule, is reproduced in this report for convenience.

MOTION PICTURES

Considerable footage of all phases of spoiler production has been acquired during this period. It is anticipated that during the coming quarter the final footage covering installation will be acquired, permitting assembly of the complete story for review by program management.

TASK II

Investigations into the feasibility and practicality of fabricating the task I aluminum components from composite materials is continuing. The design and research effort by NASA-Langley is continuing, with promising results anticipated. In addition, one industry source has proposed a novel, two-step approach to the integrated hinge fitting design problem which appears quite attractive. The integrated hinge fitting/spar unit should advance to the committed design stage during the coming quarter.

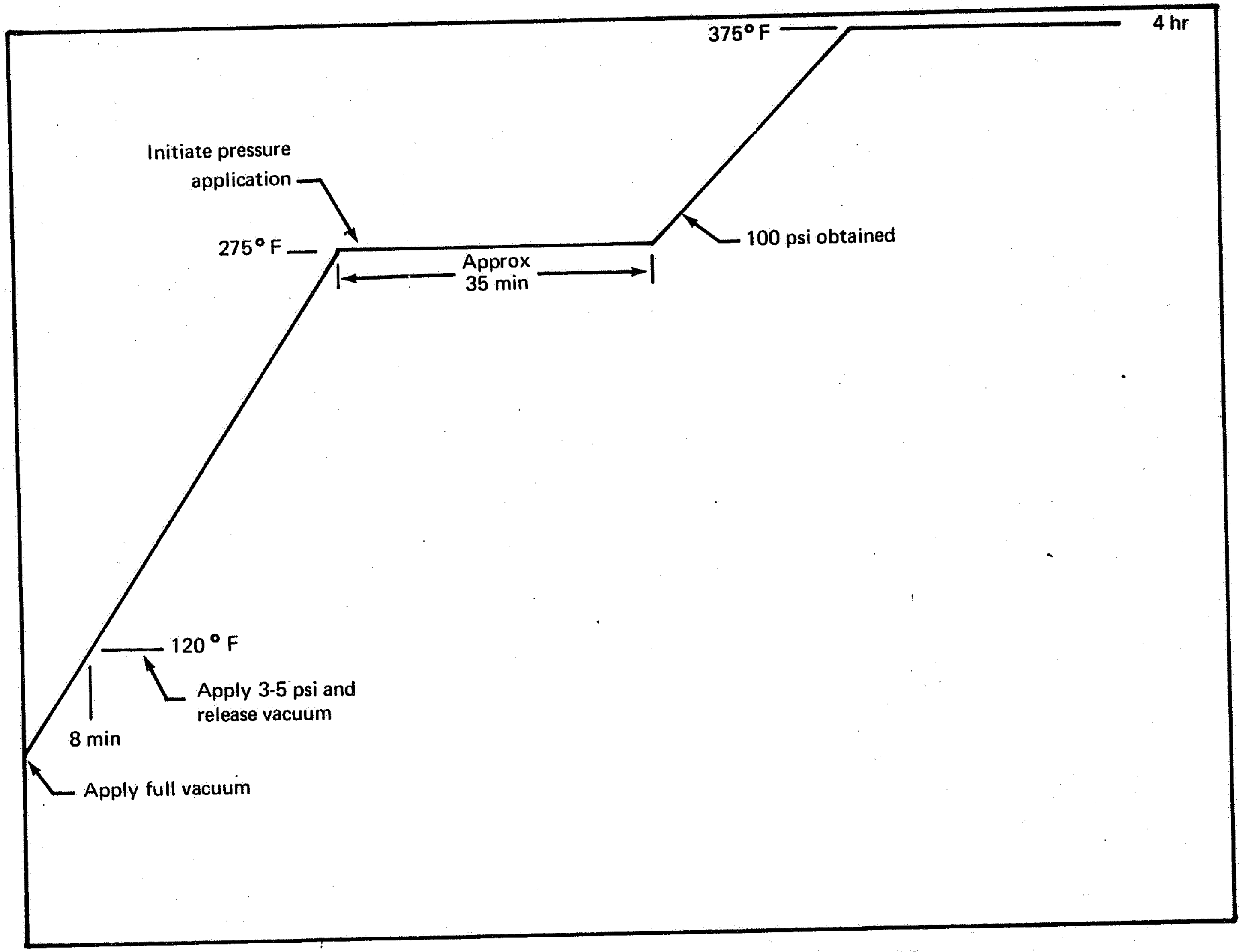

FIGURE 1.—CURE CYCLE—UNION CARBIDE 2544

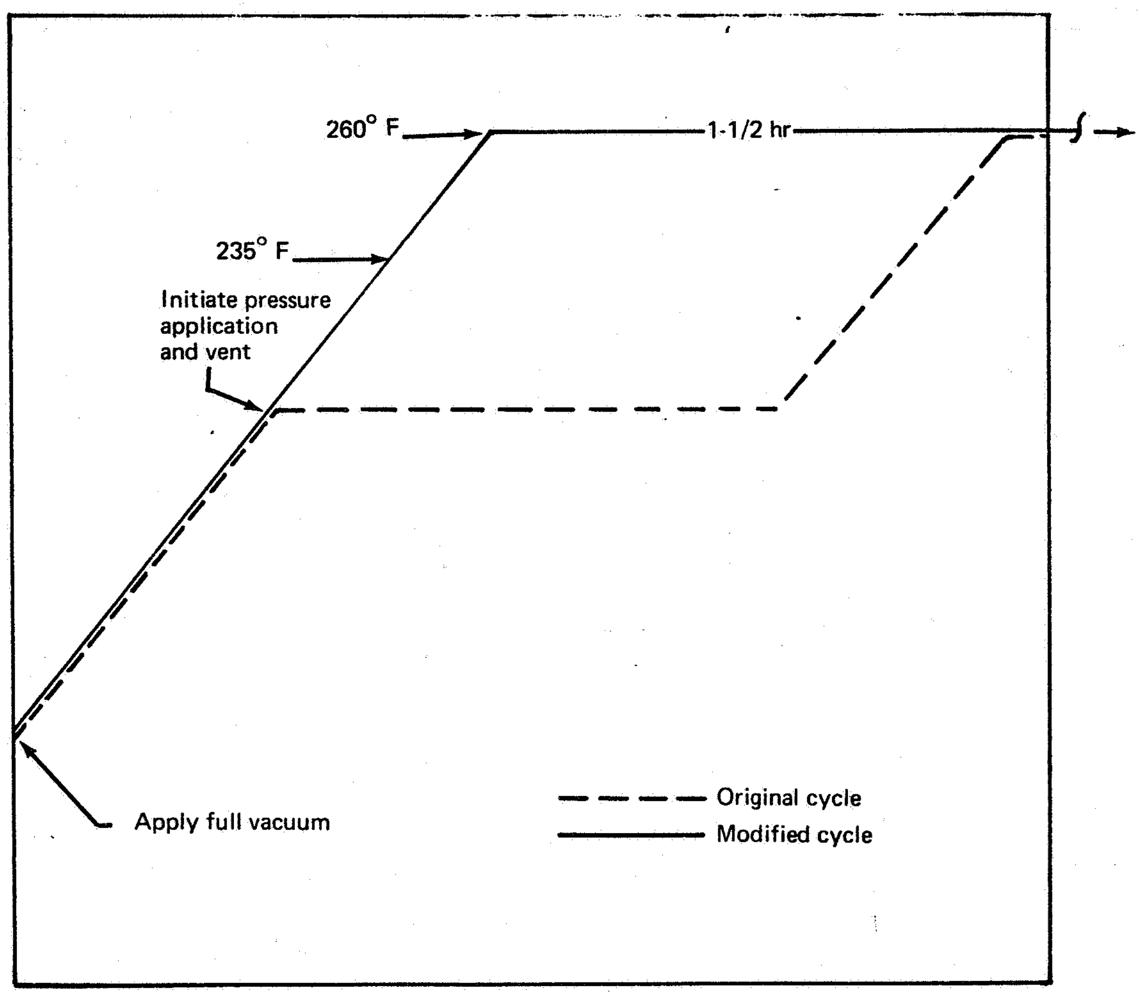

FIGURE 2.—CURE CYCLE—NARMCO 5209

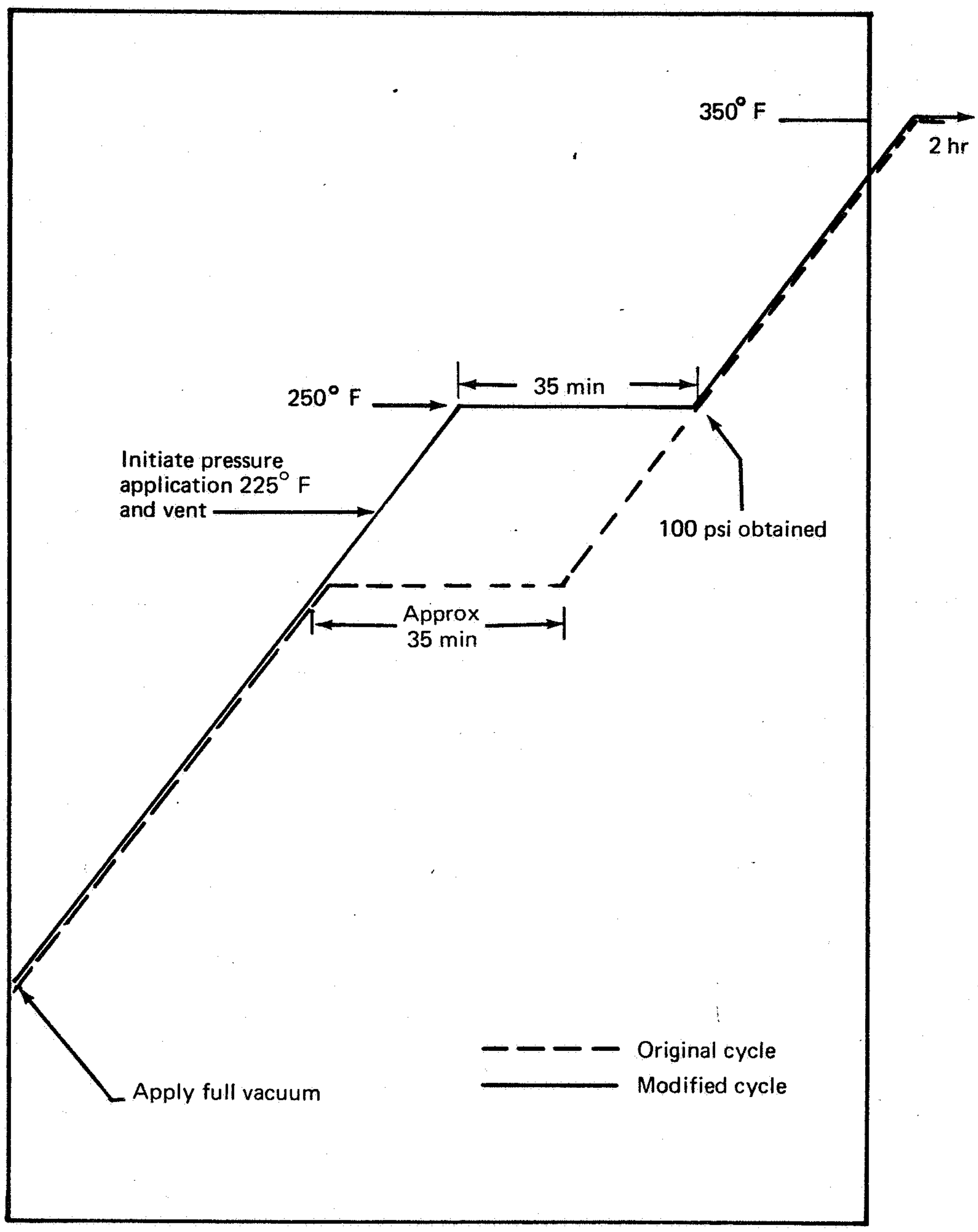

FIGURE 3.—CURE CYCLE—HERCULES X3501

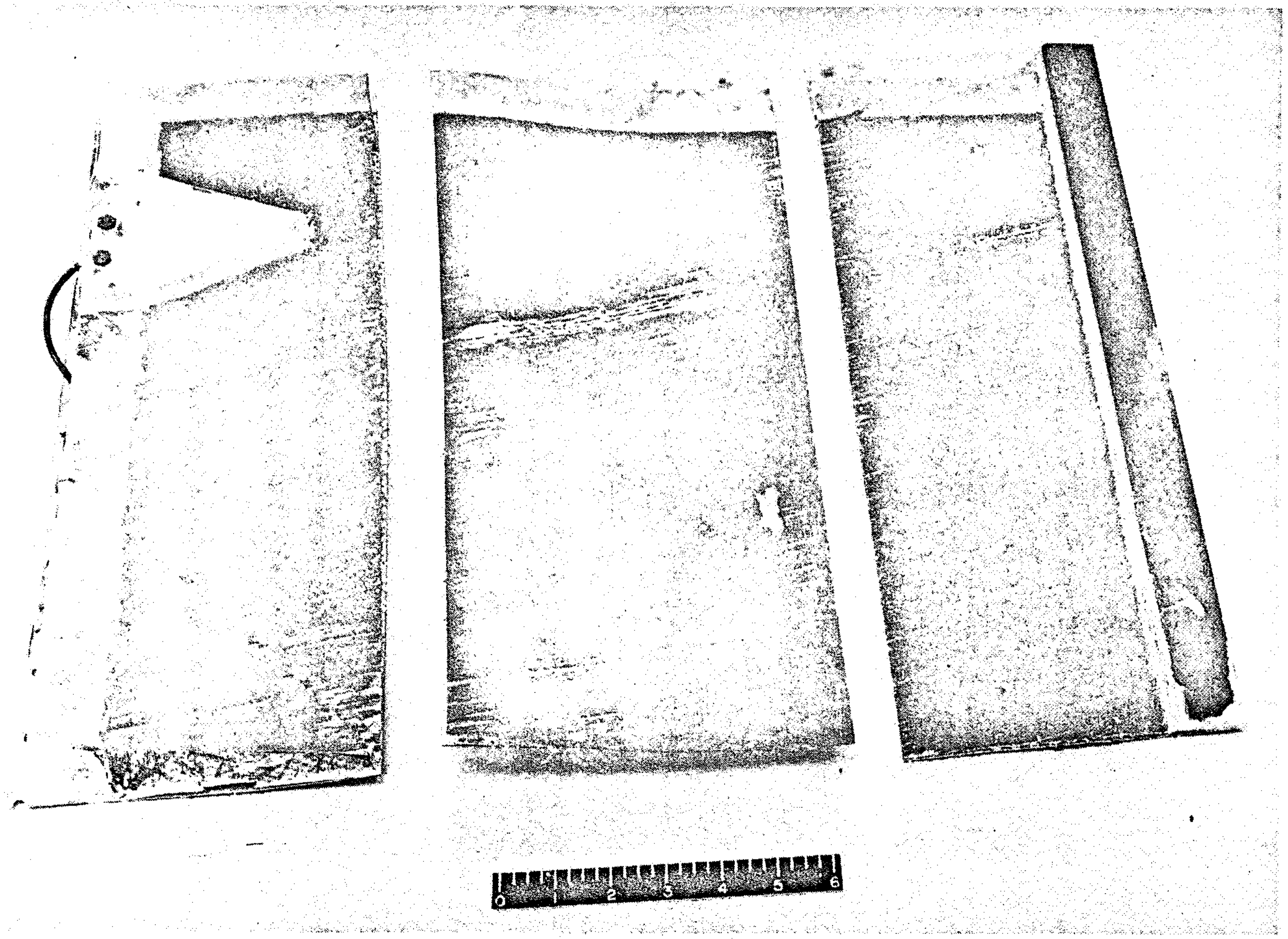

FIGURE 4.—CHEM-MILLED SECTIONS OF –3 TEST SPOILER

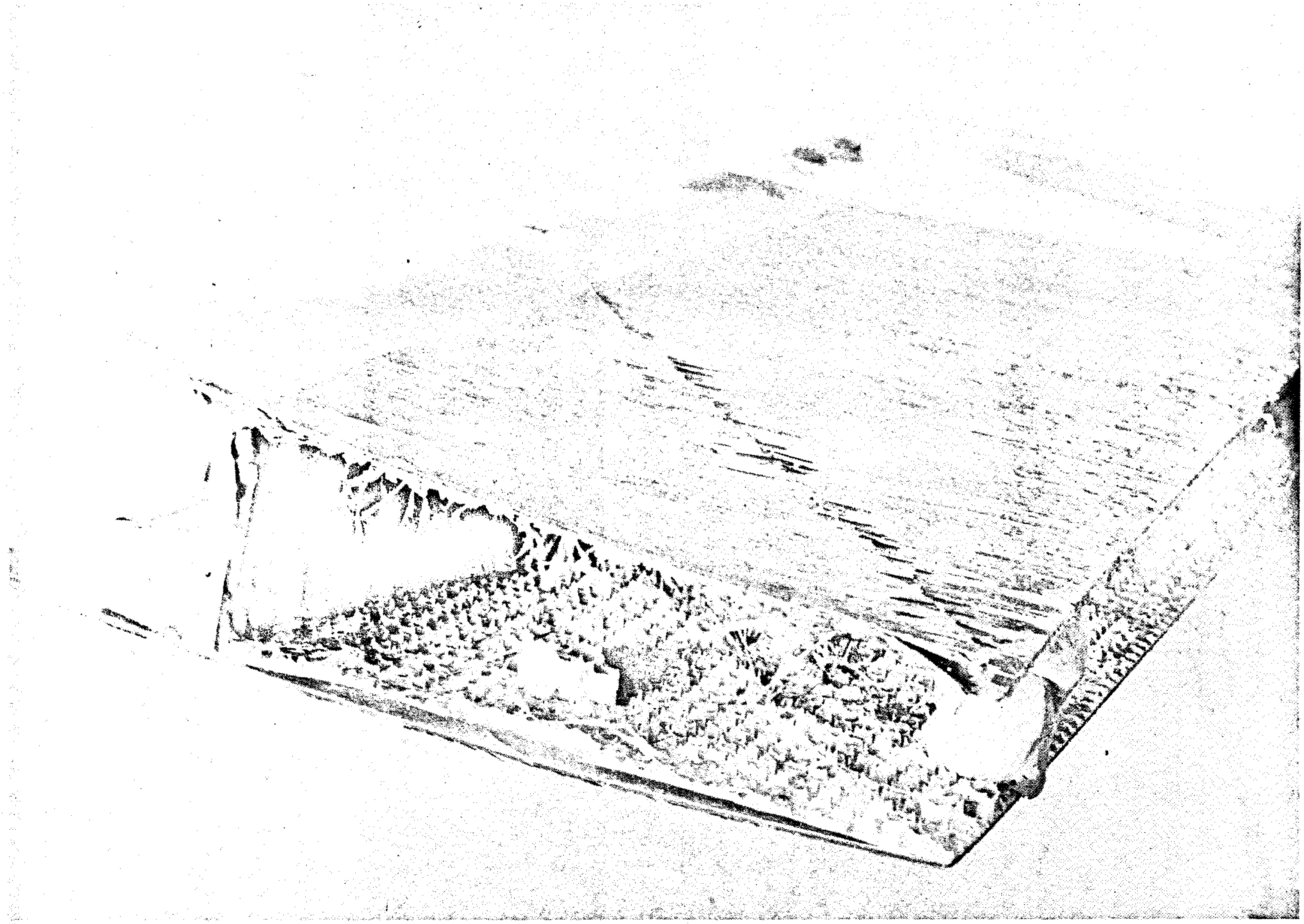

FIGURE 5.—ADHESIVE FILLETING NEAR LEADING EDGE

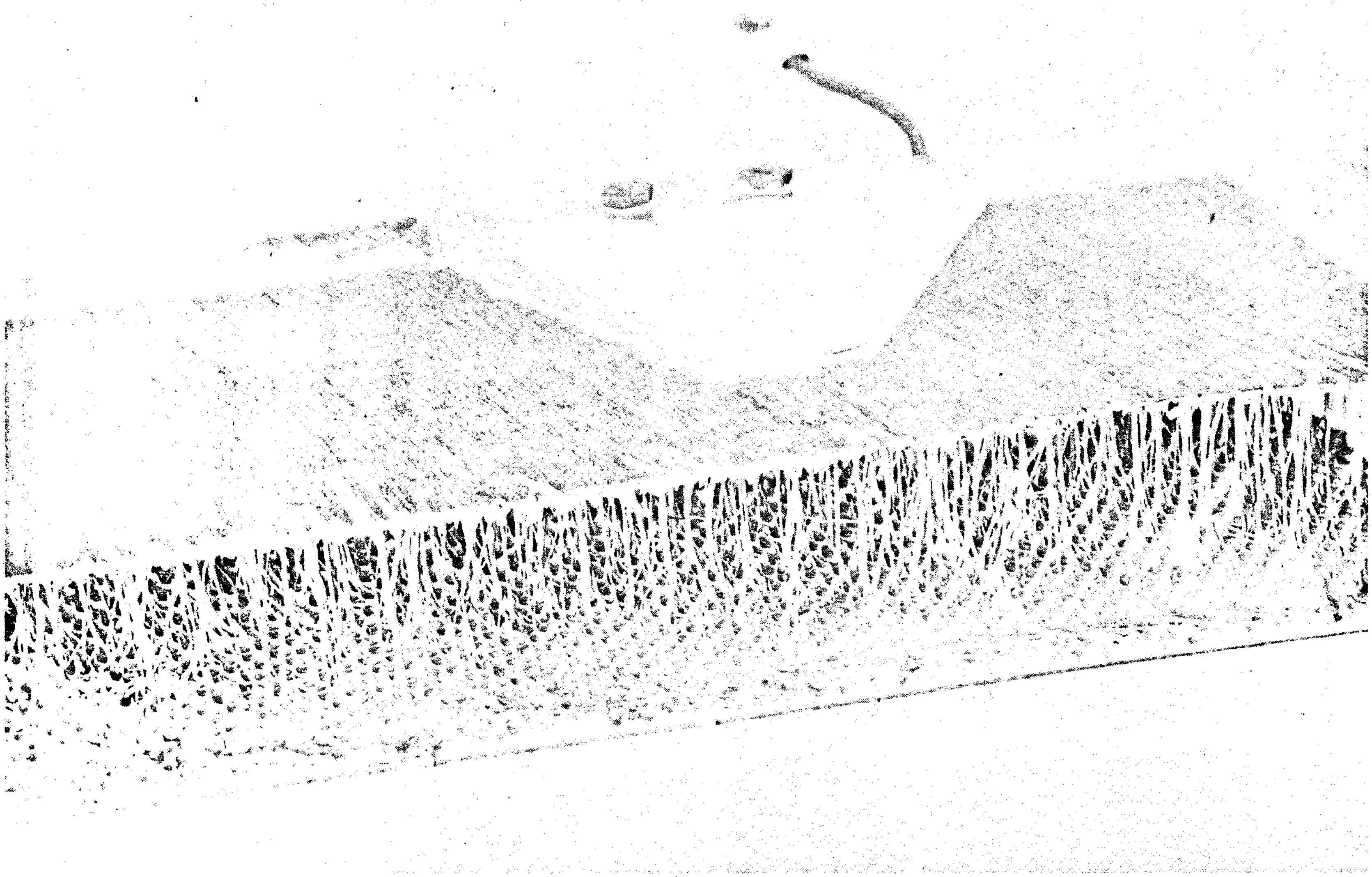

FIGURE 6.—ADHESIVE FILLETING AND CORE NODE BONDING

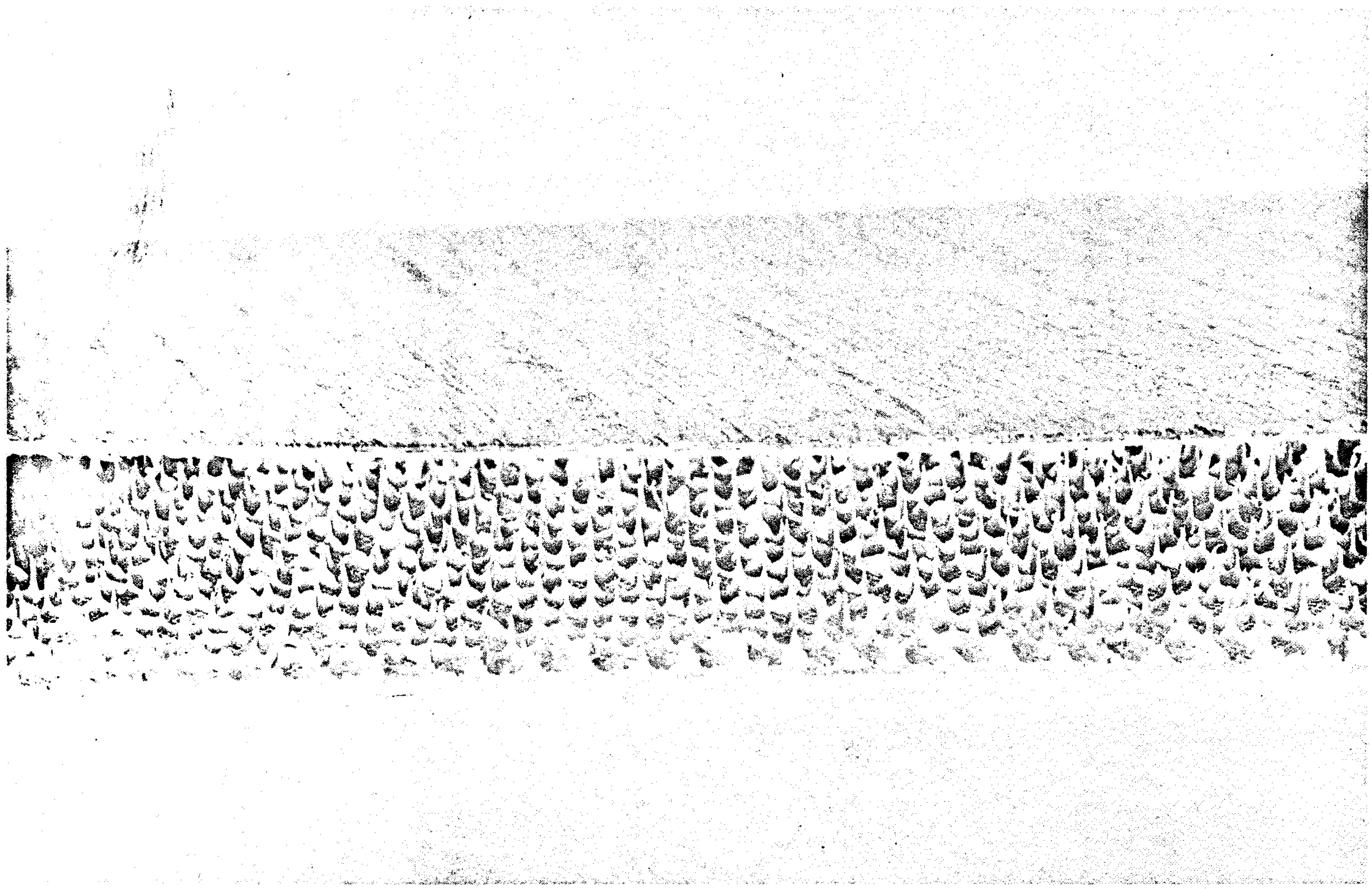

FIGURE 7.—CLOSEUP OF SKIN-TO-CORE ADHESIVE FILLETING

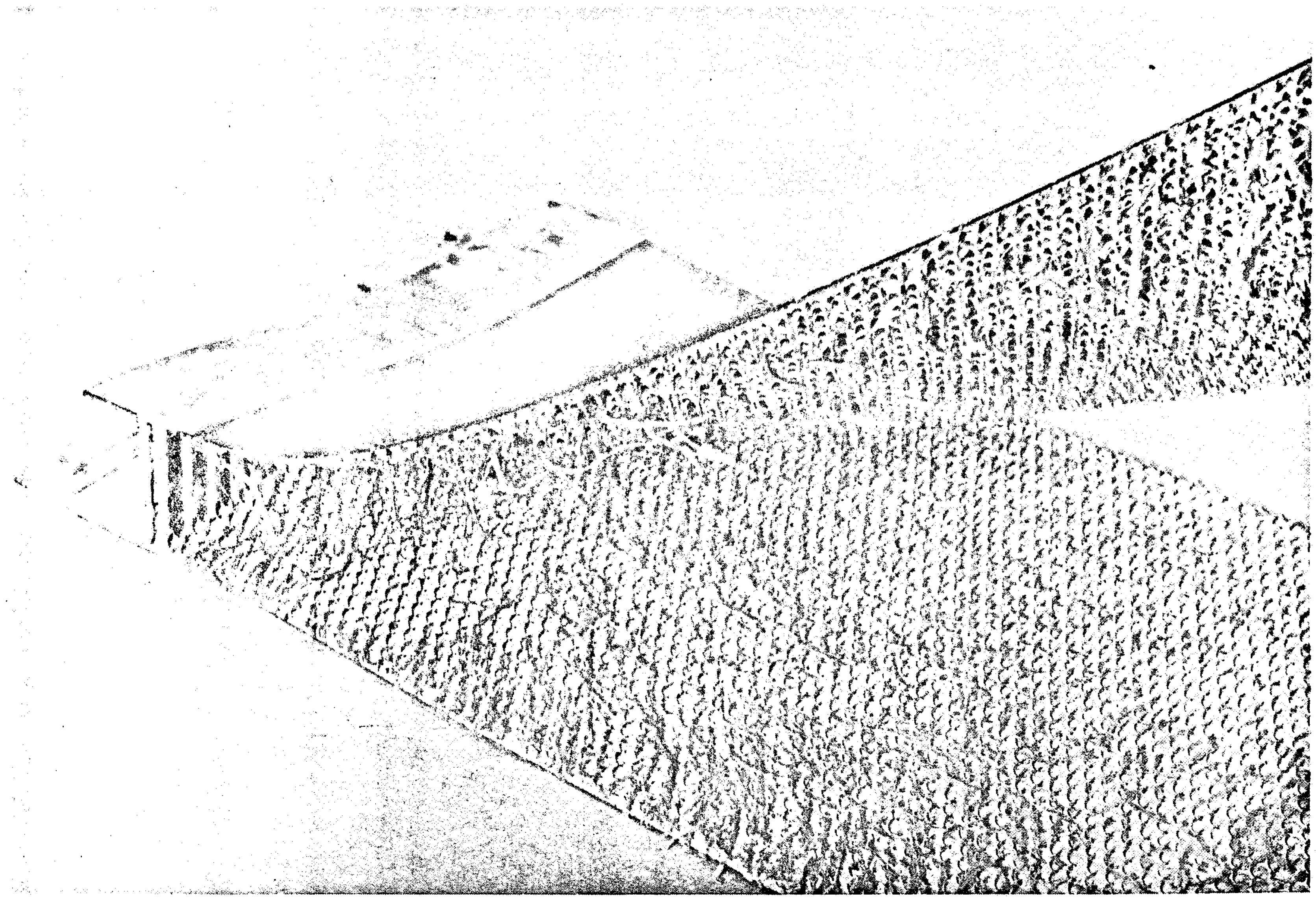

FIGURE 8.—ADHESIVE FILLETING AND CORE NODE BONDS, TRANSITION SECTION

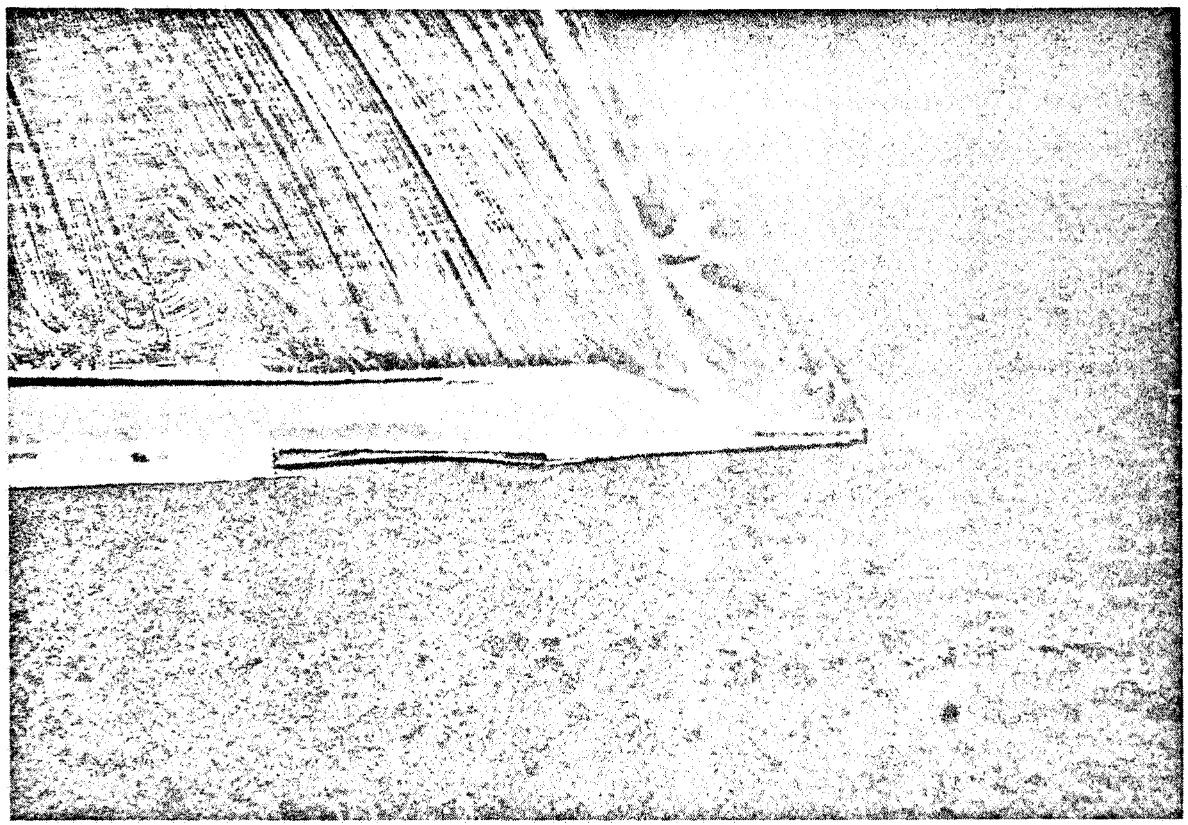

FIGURE 9.—DAMAGED SKIN AND END RIB, SPOILER S/N 0005

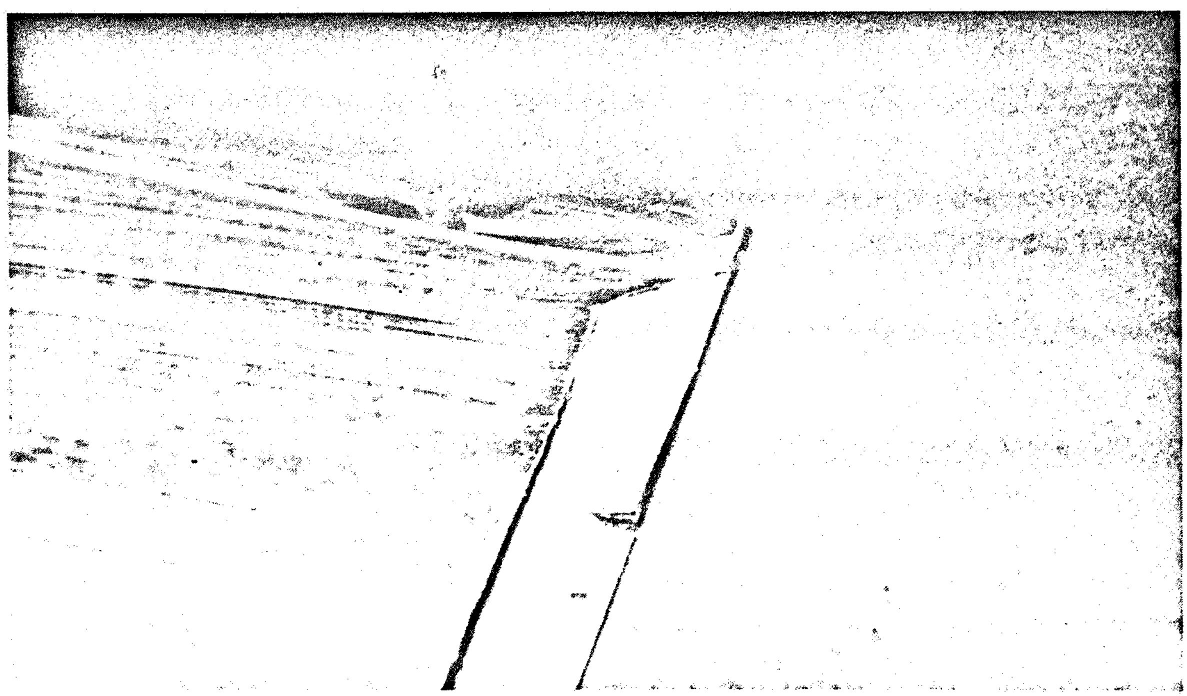

FIGURE 10.—DAMAGED SKIN AND END RIB, SPOILER S/N 0005

FIGURE 11.—COMPLETED REPAIR, FIBERGLASS END RIB, SPOILER S/N 0005

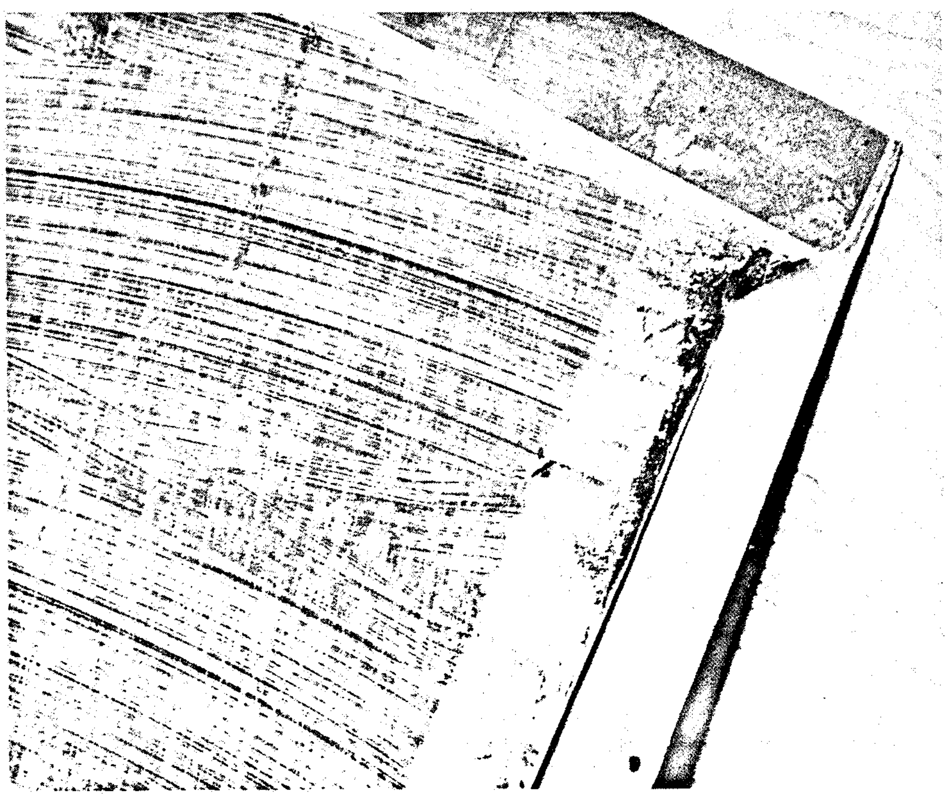

FIGURE 12.—COMPLETED REPAIR, FIBERGLASS END RIB, SPOILER S/N 0005

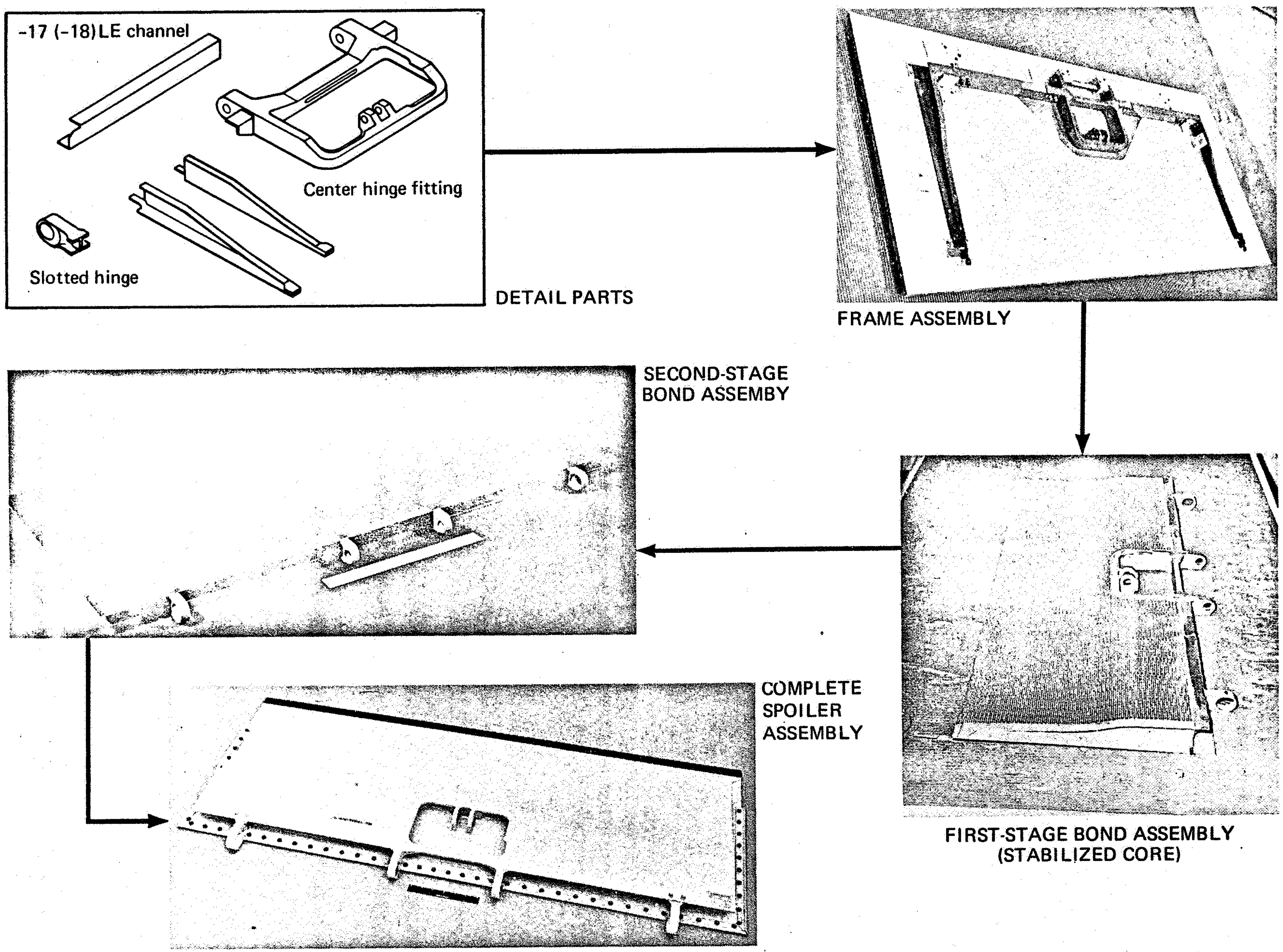

FIGURE 13.—SPOILER ASSEMBLY SEQUENCE

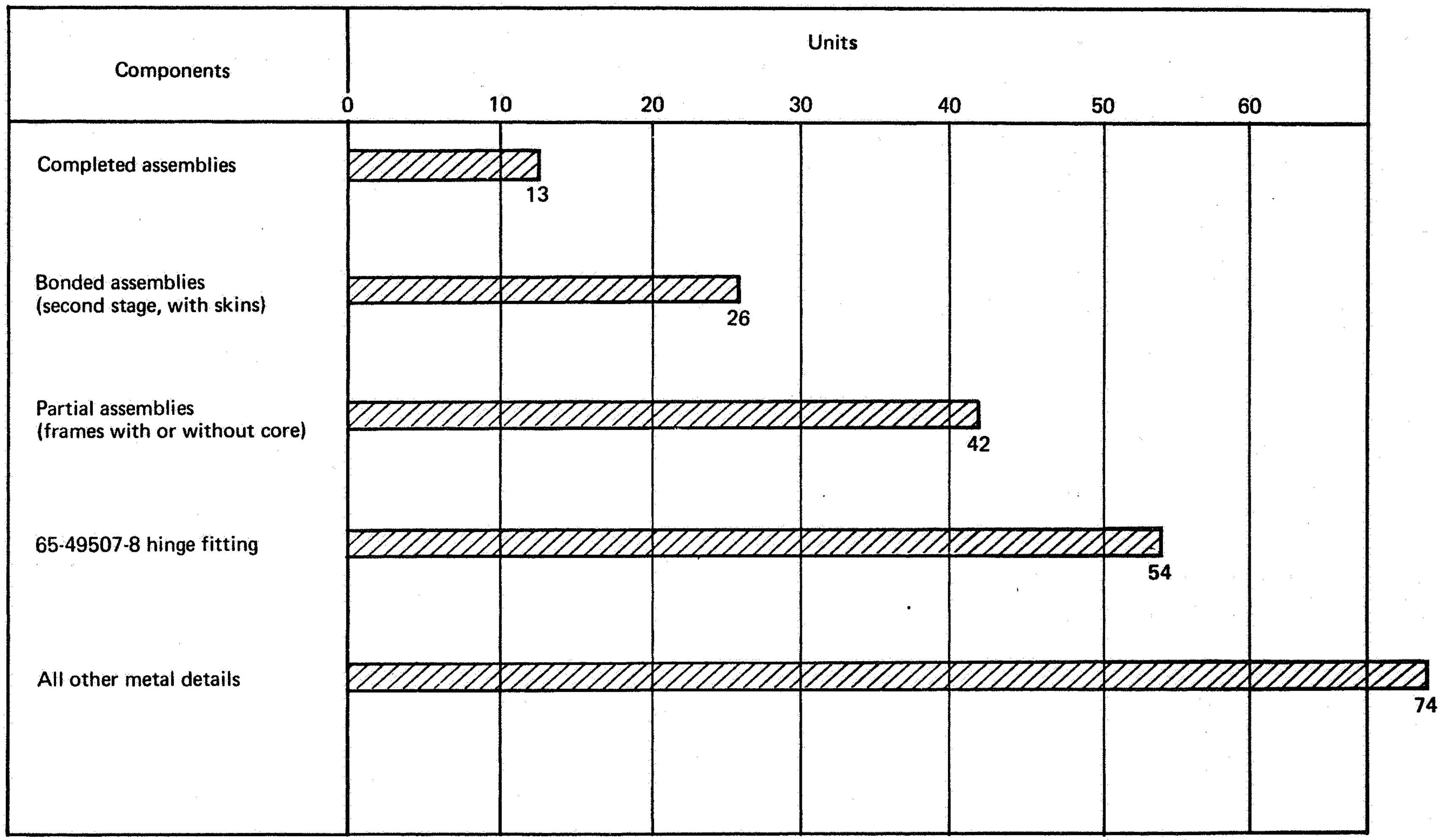

FIGURE 14.—PRODUCTION STATUS (AS OF MARCH 31, 1973)

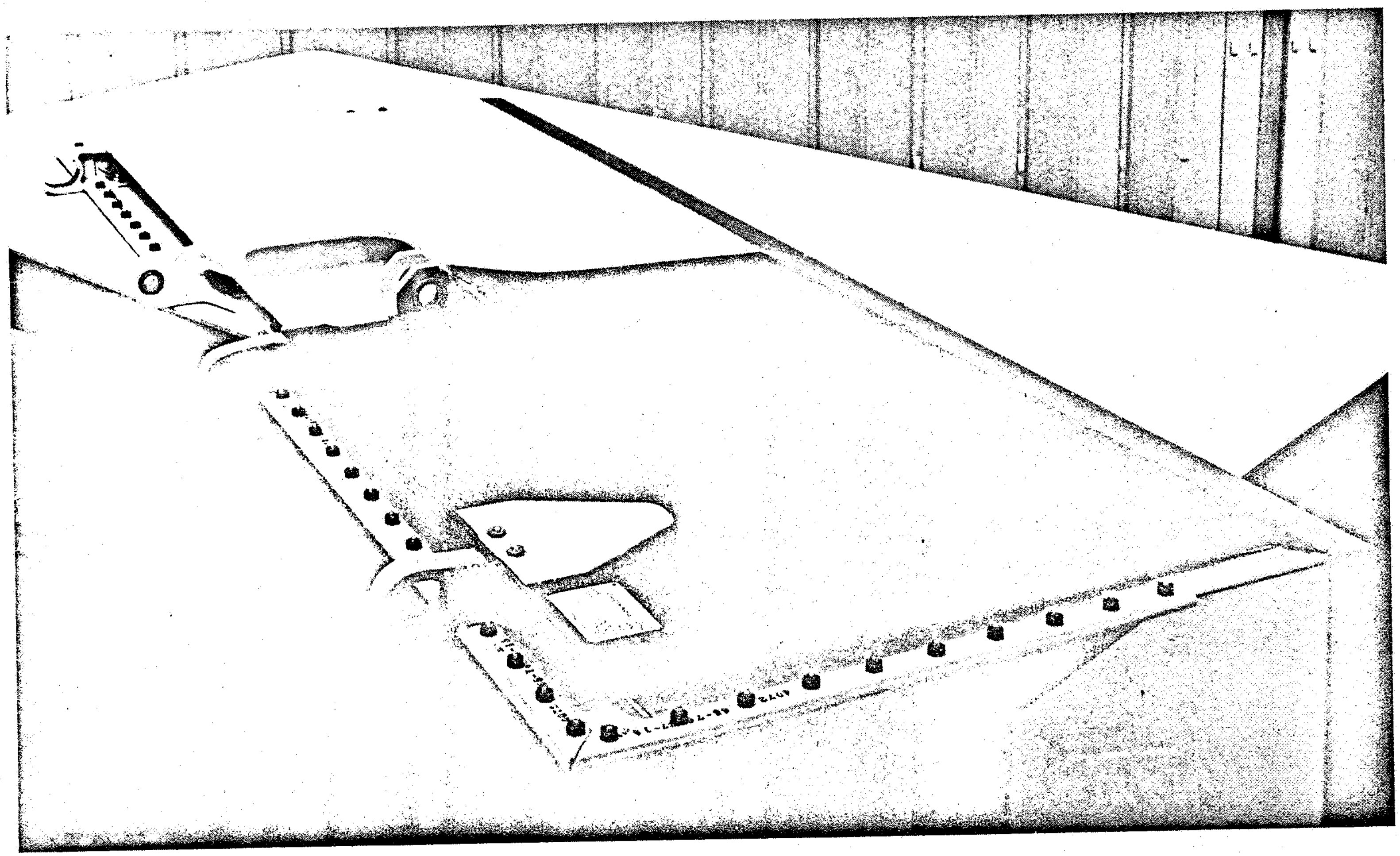

FIGURE 15.—SPOILER S/N 0001—NASA DISPLAY MODEL

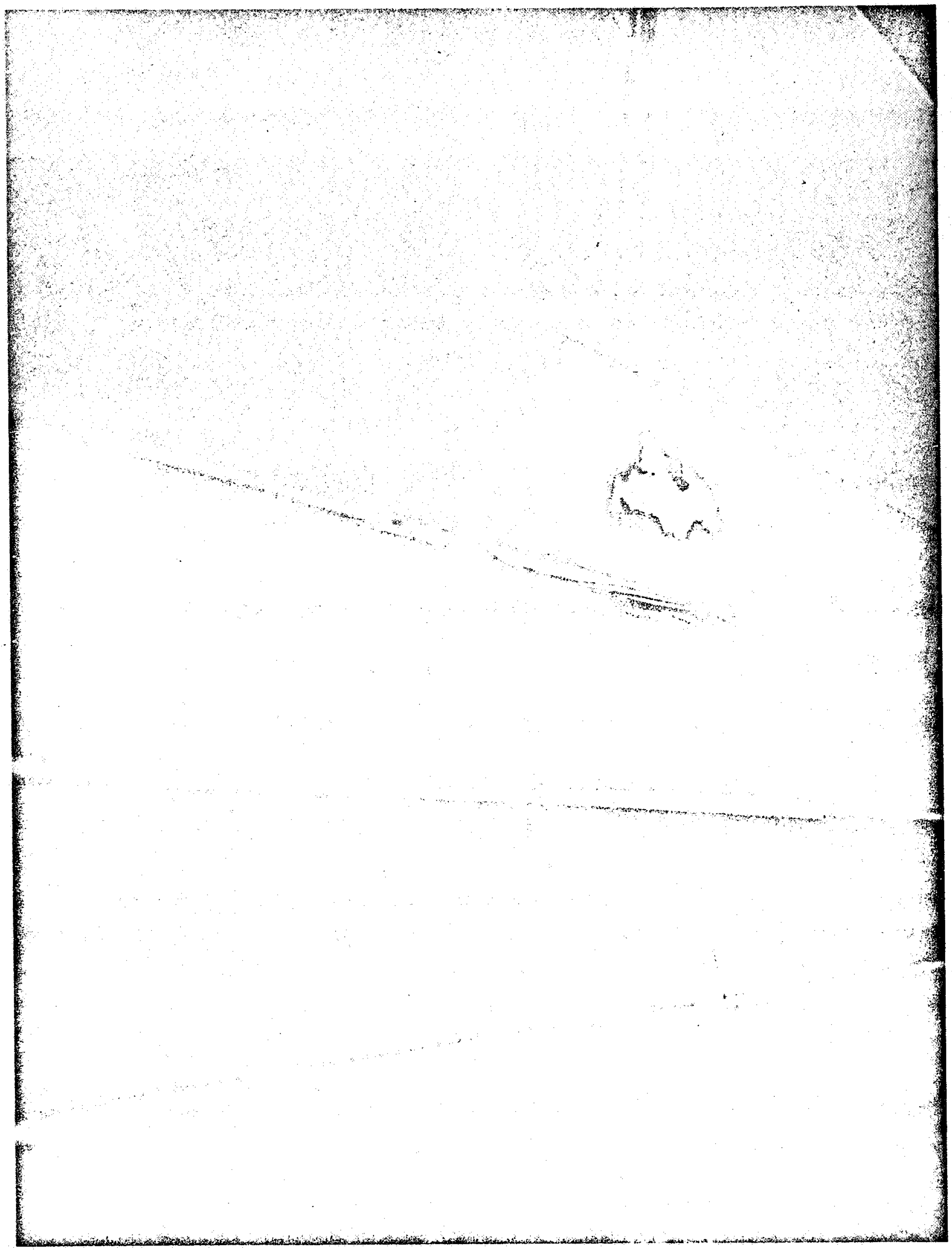

*FIGURE 16.—GRAPHITE PREPREG TAPE SAMPLES—
REPRESENTATIVE REJECTABLE CONDITIONS*

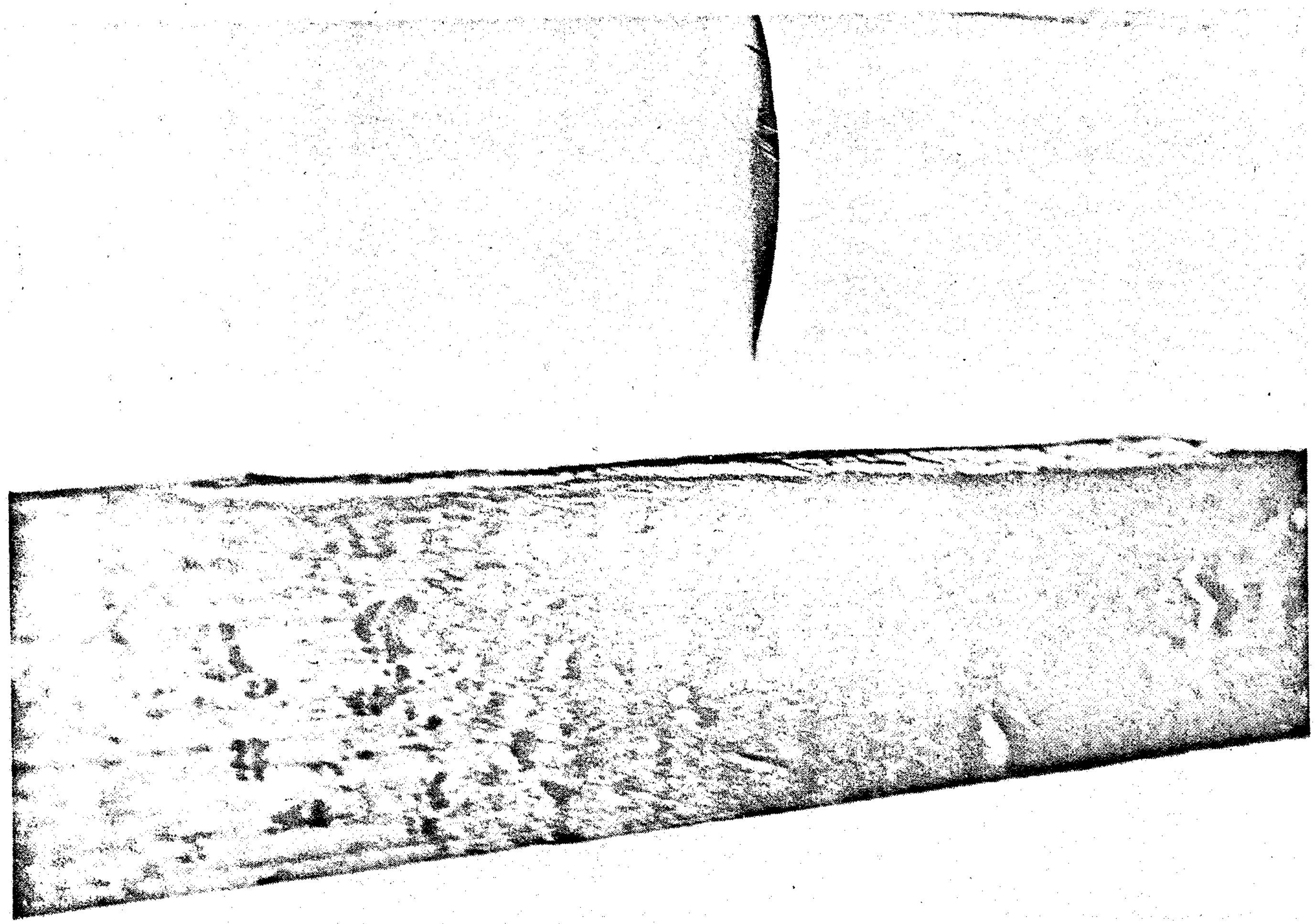

FIGURE 17.—GRAPHITE PREPREG TAPE SAMPLES—REPRESENTATIVE REJECTABLE CONDTIONS

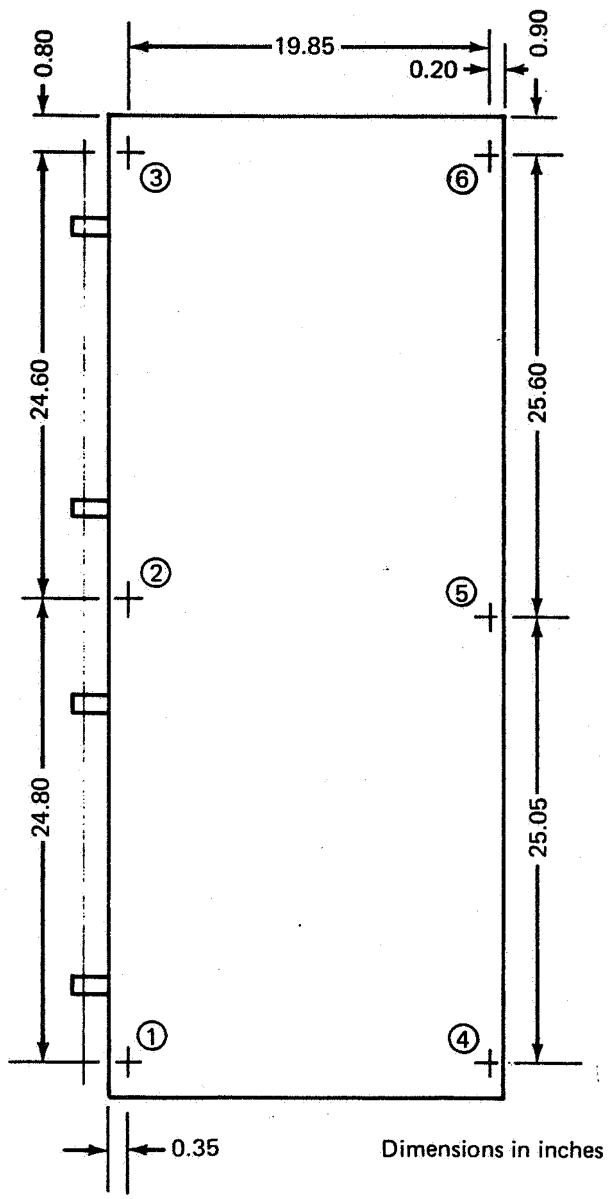

FIGURE 18.–DEFLECTION GAGE LOCATIONS–STATIC TEST

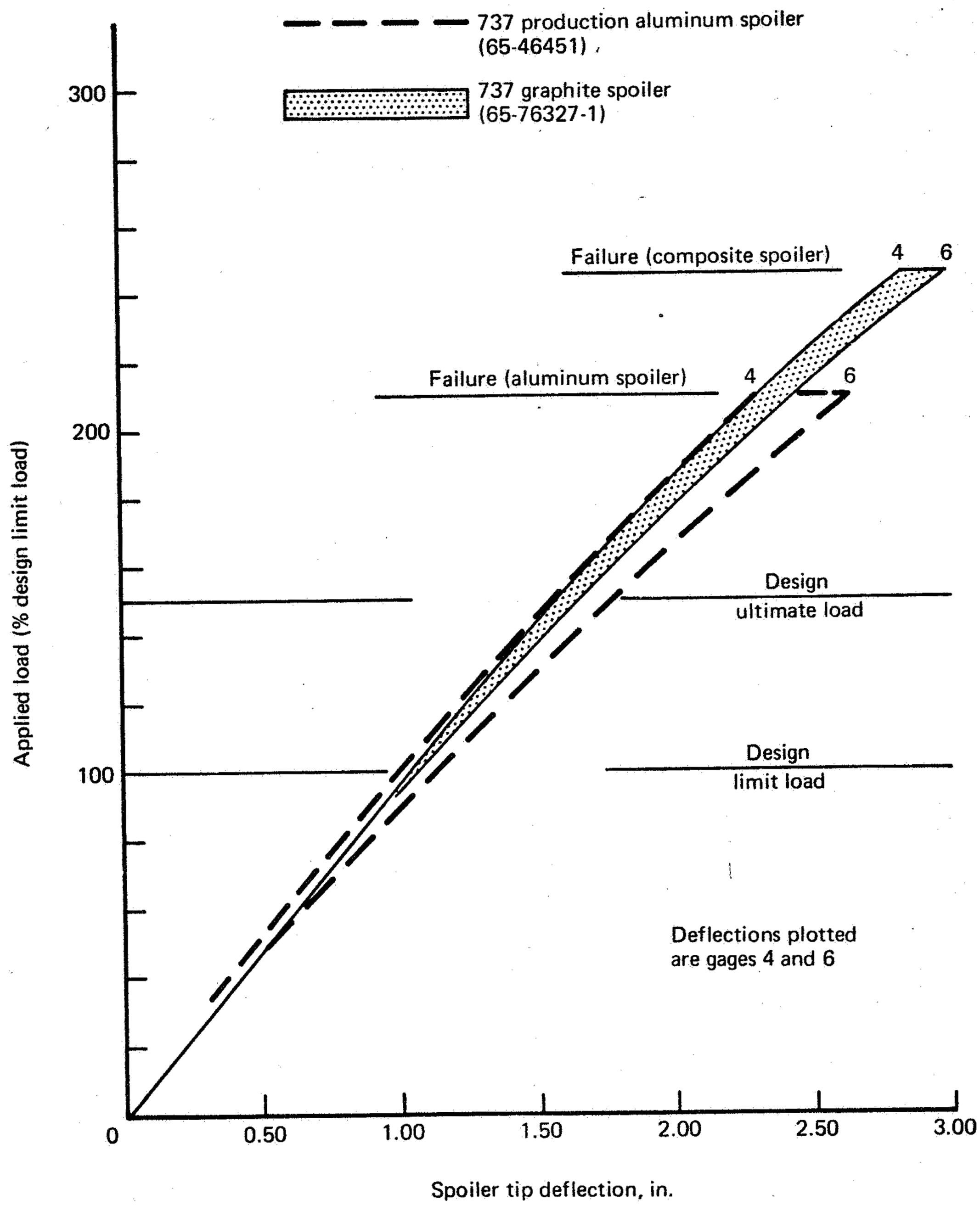

FIGURE 19.—GRAPHITE SPOILER TIP STIFFNESS (UNION CARBIDE, 65-76327-1)

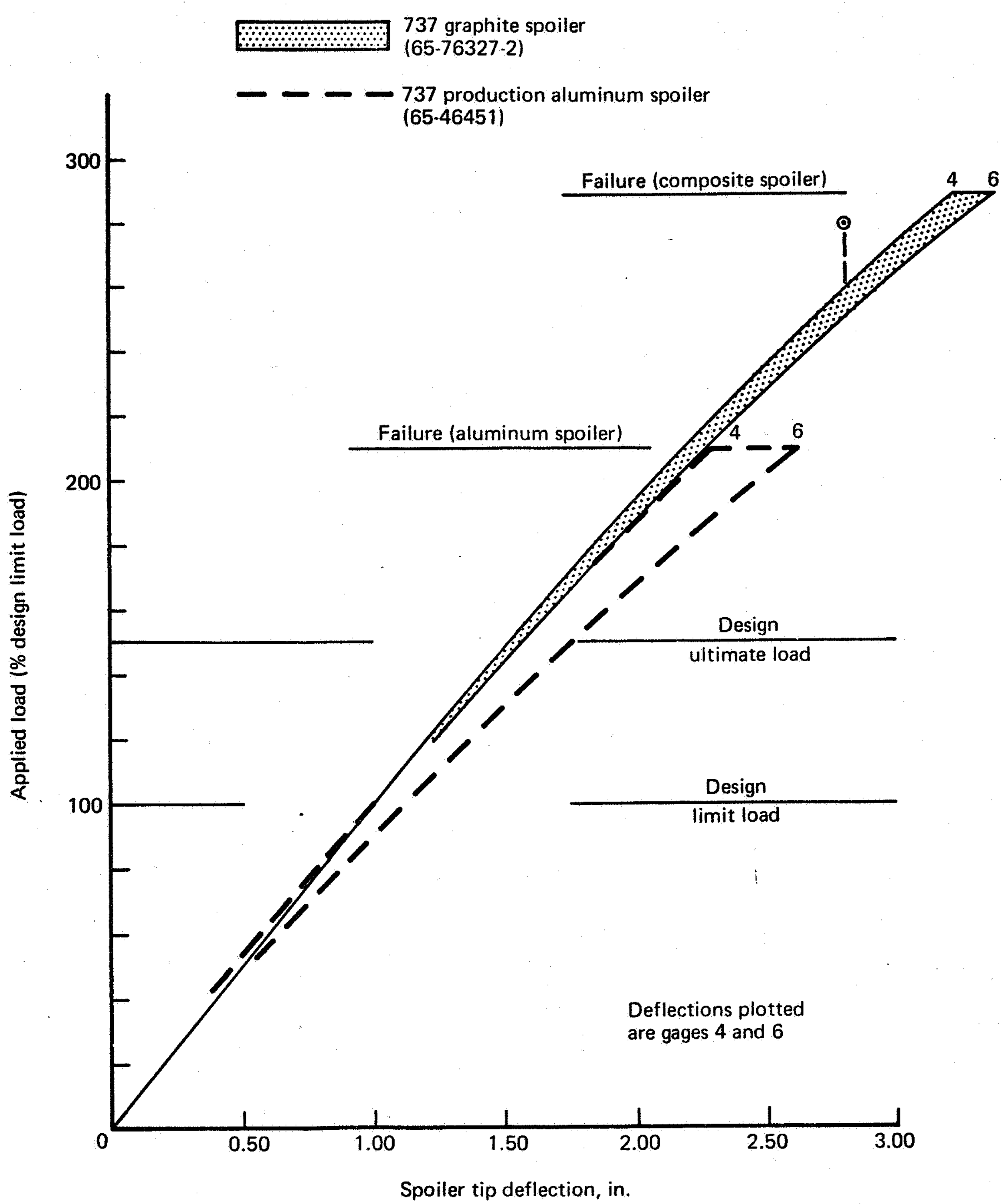

FIGURE 20.—GRAPHITE SPOILER TIP STIFFNESS (NARMCO 65-76327-2)

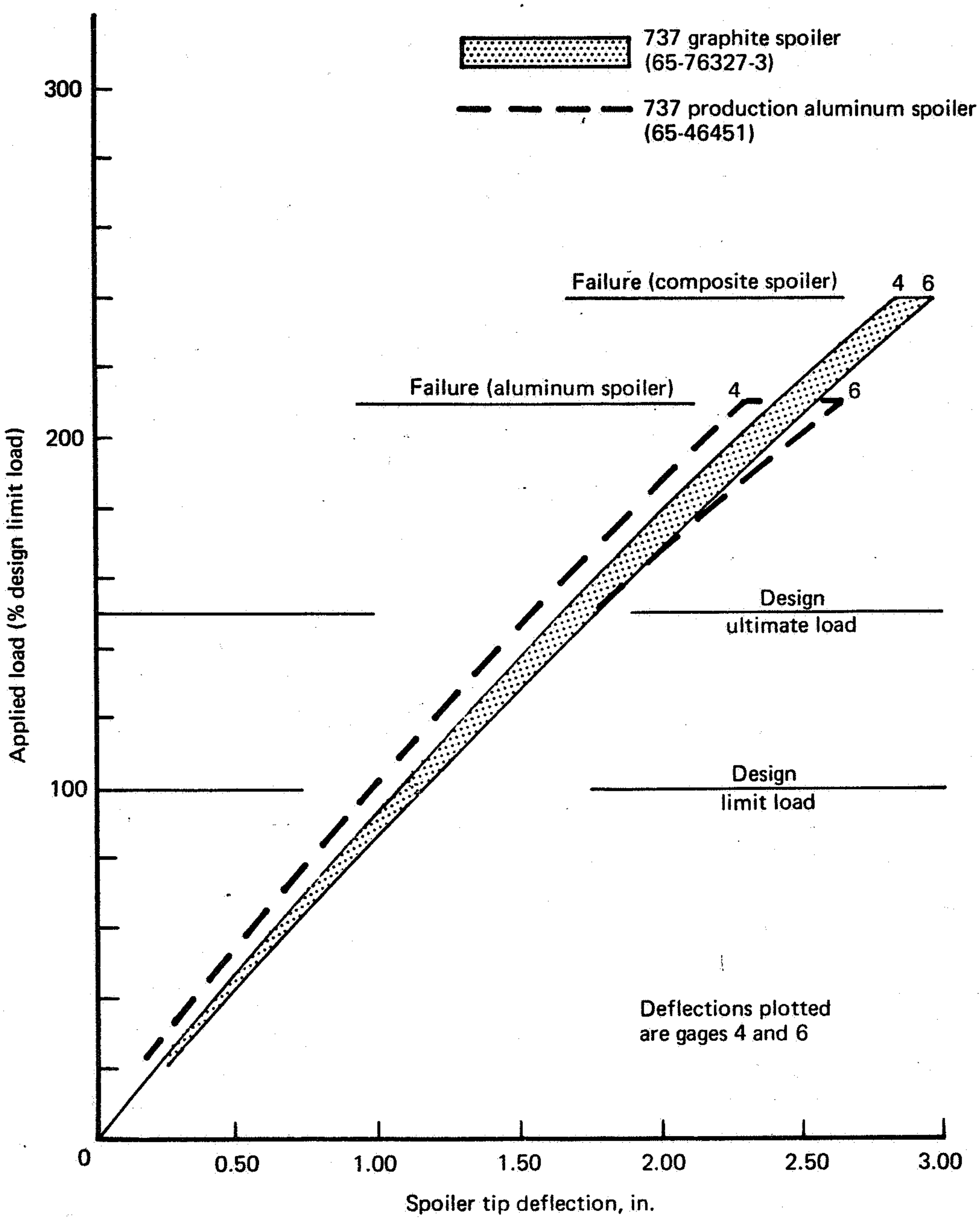

FIGURE 21.—GRAPHITE SPOILER TIP STIFFNESS (HERCULES 65-76327-3)

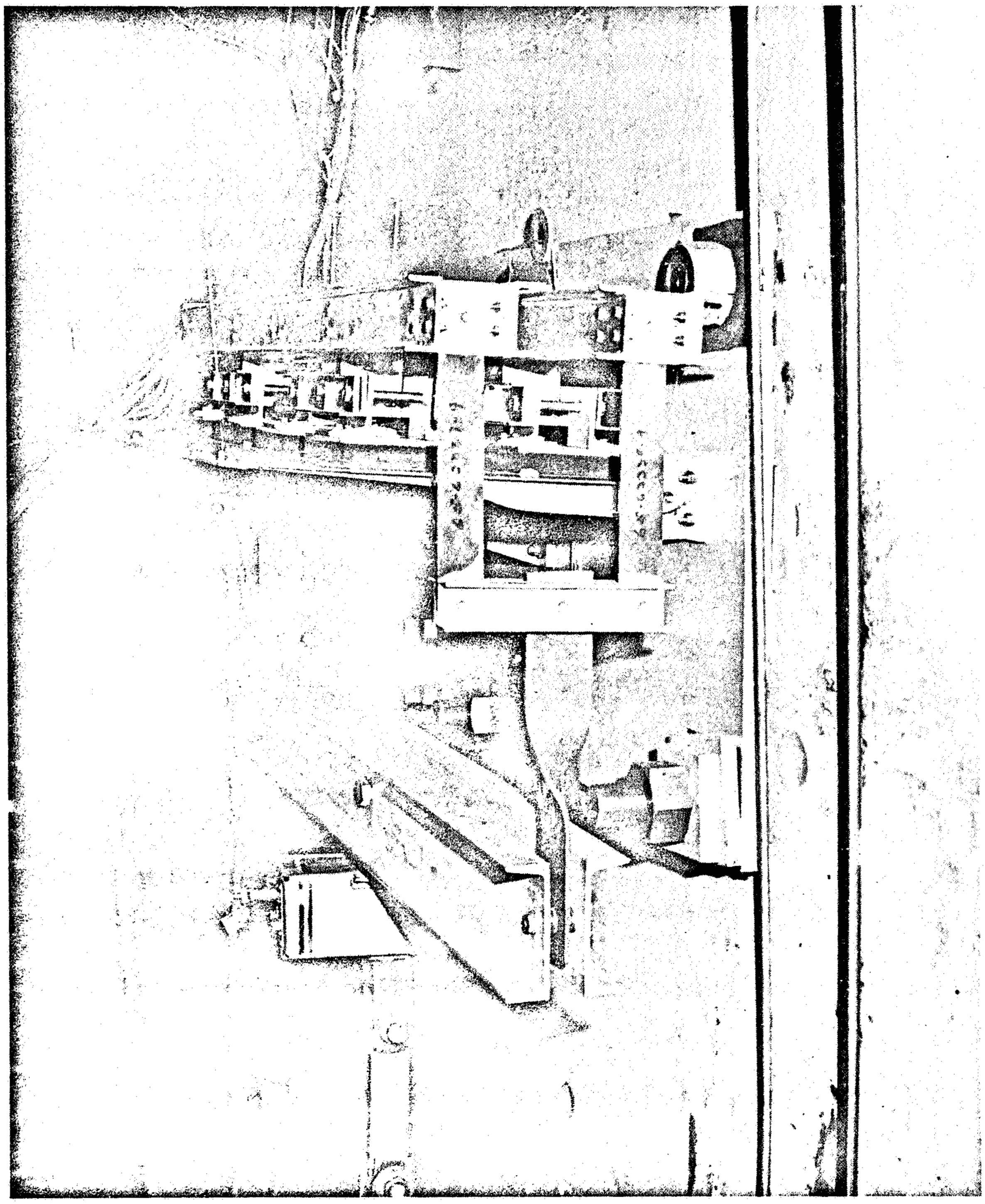

FIGURE 22.—SPOILER STATIC TEST SETUP

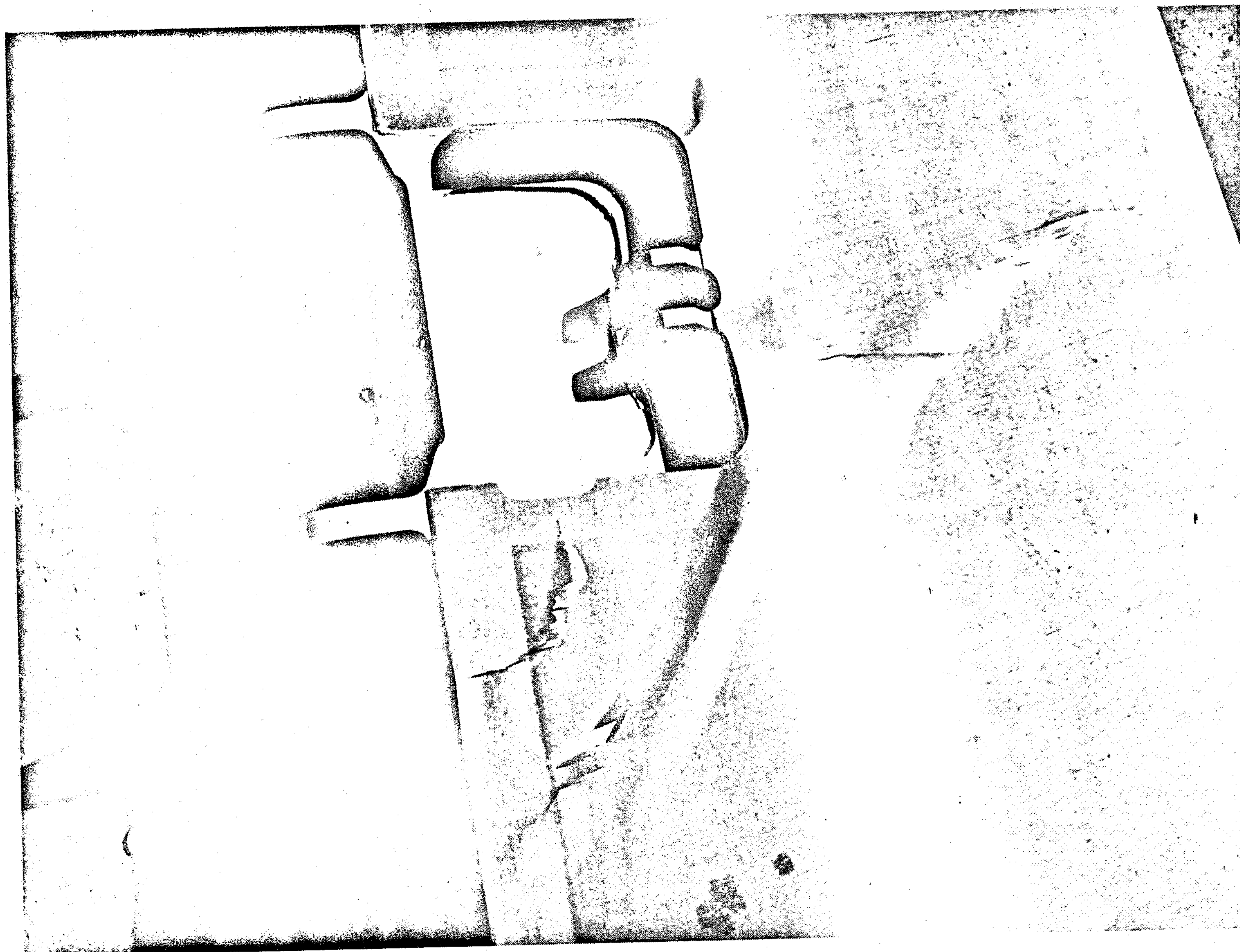

FIGURE 23.—LOWER SURFACE FAILURE—GRAPHITE-EPOXY SPOILER (UNION CARBIDE, 65-76327-1)

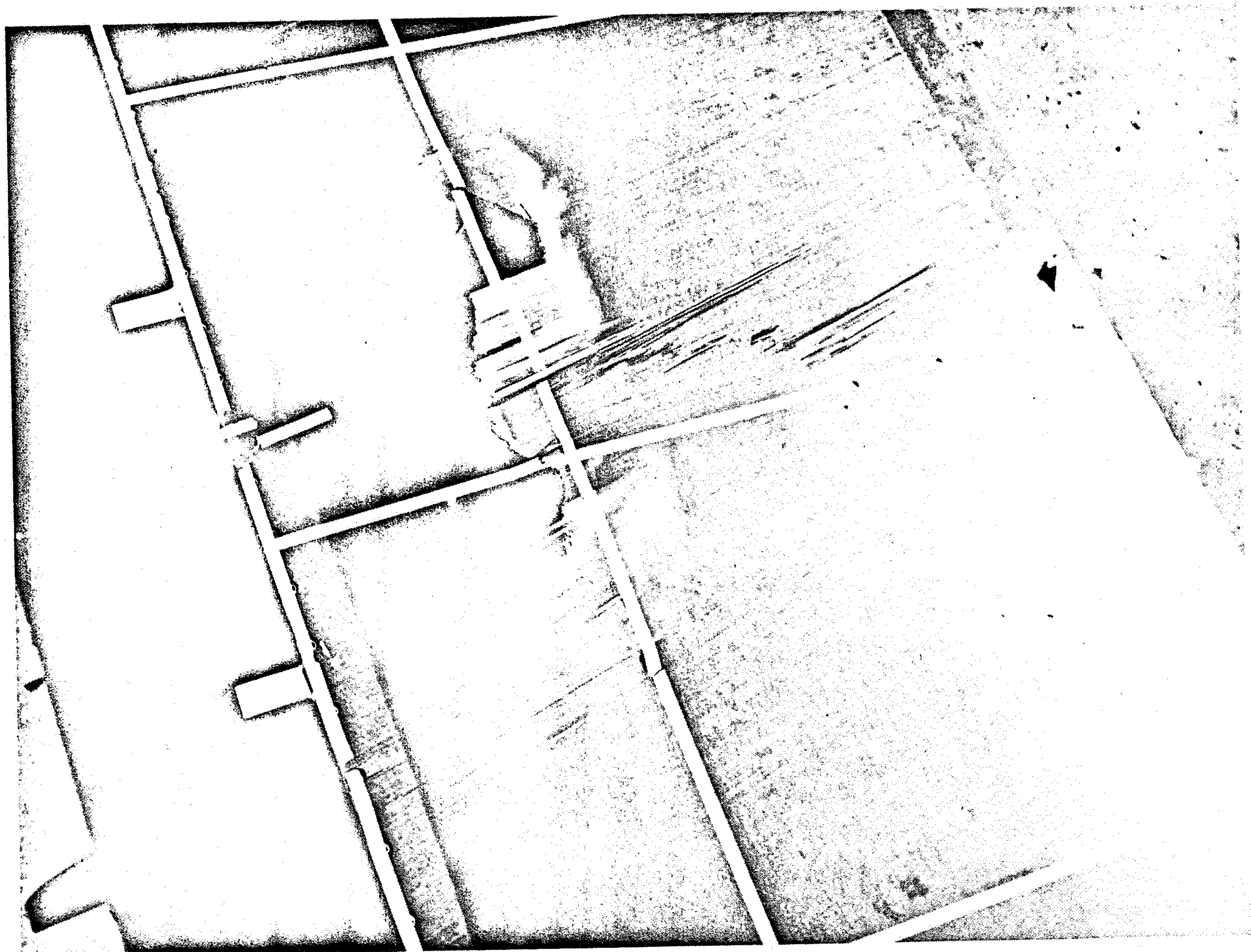

FIGURE 24.—UPPER SURFACE FAILURE—GRAPHITE-EPOXY SPOILER (UNION CARBIDE, 65-76327-1)

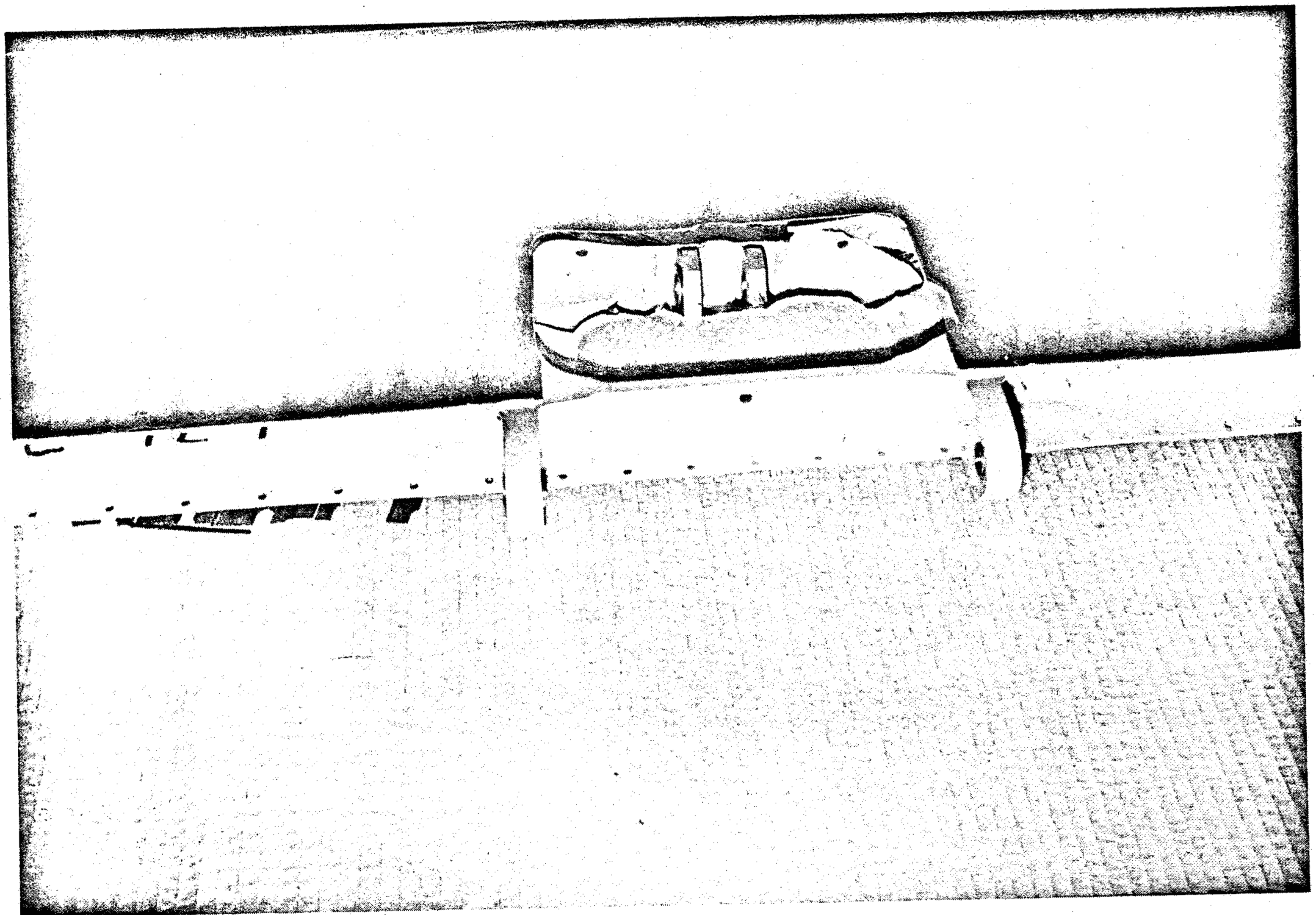

FIGURE 25.—LOWER SURFACE FAILURE—GRAPHITE-EPOXY SPOILER (NARMCO, 65-76327-2)

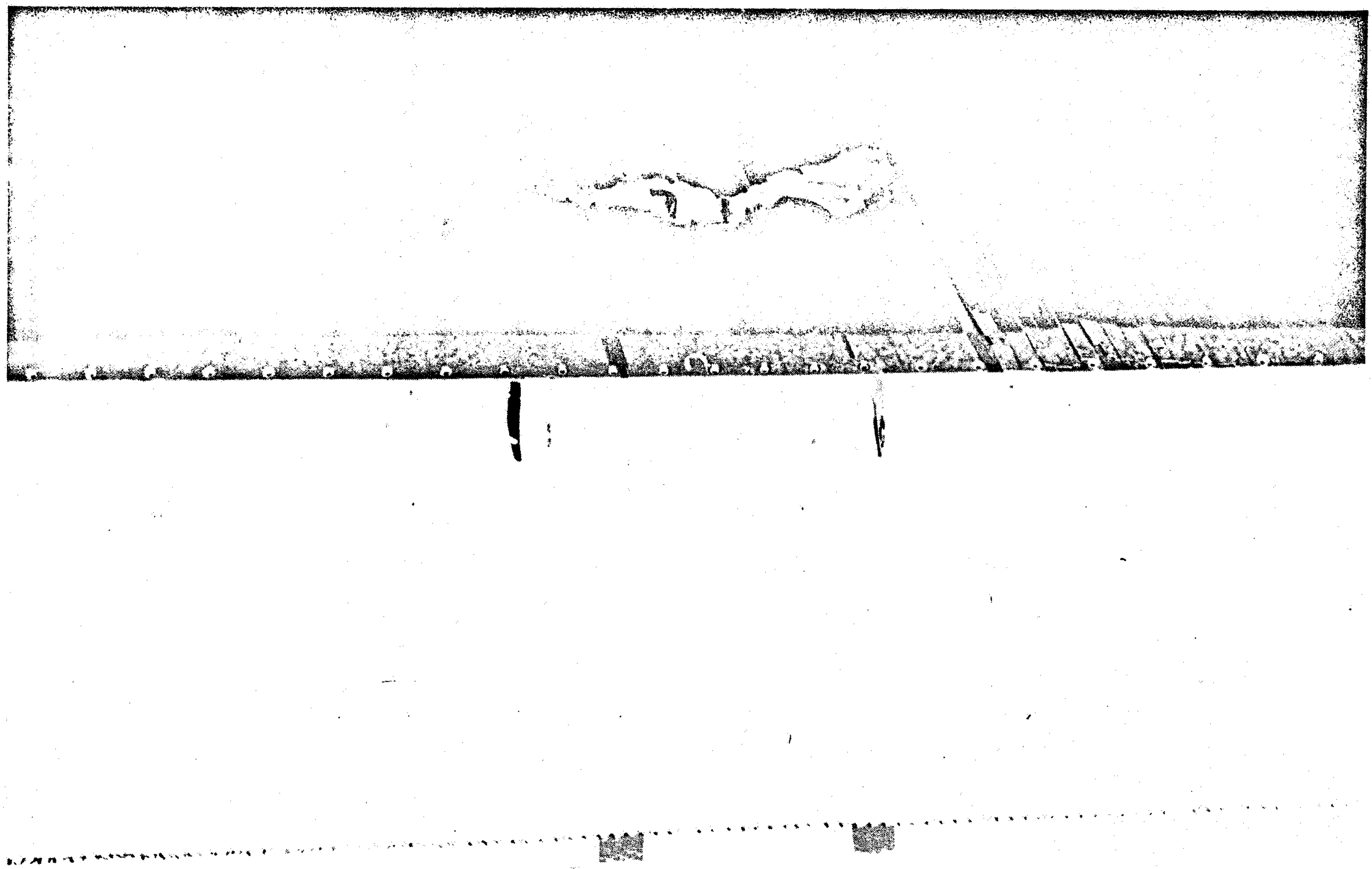

FIGURE 26.—UPPER SURFACE FAILURE—GRAPHITE-EPOXY SPOILER (NARMCO, 65-76327-2)

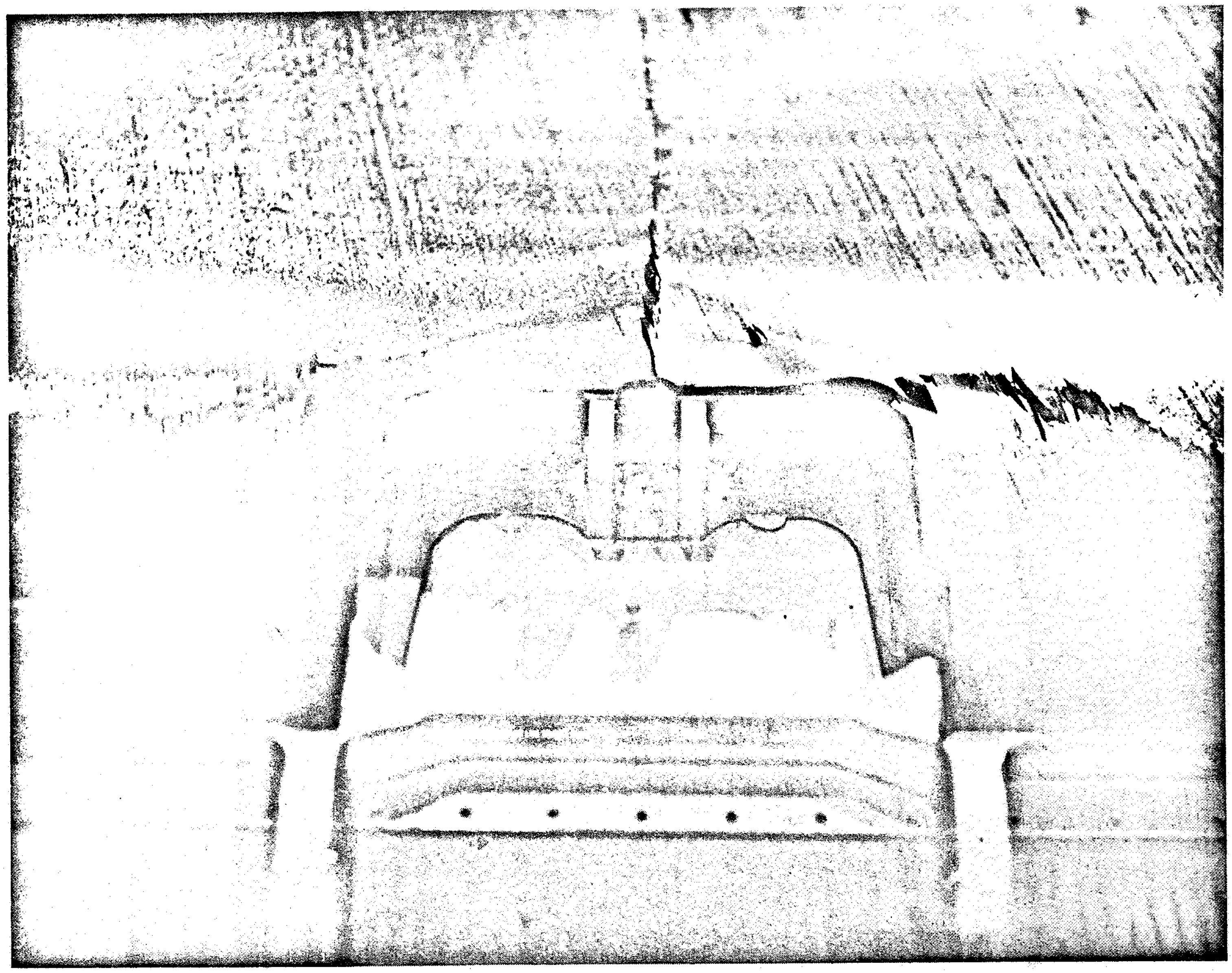

FIGURE 27.—LOWER SURFACE FAILURE—GRAPHITE-EPOXY SPOILER (HERCULES, 65-76327-3)

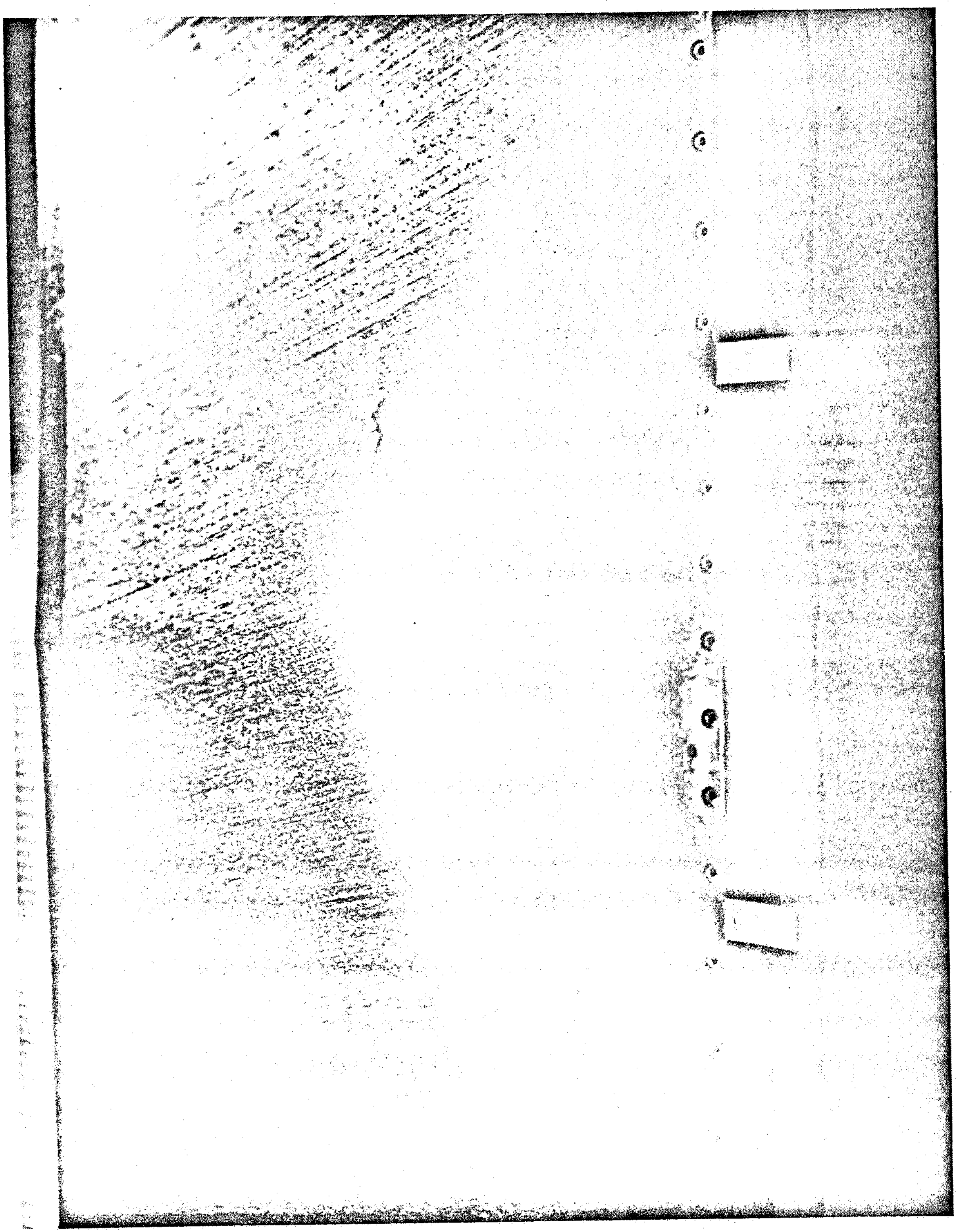

FIGURE 28.—UPPER SURFACE FAILURE—GRAPHITE-EPOXY SPOILER (HERCULES, 65-76327-3)

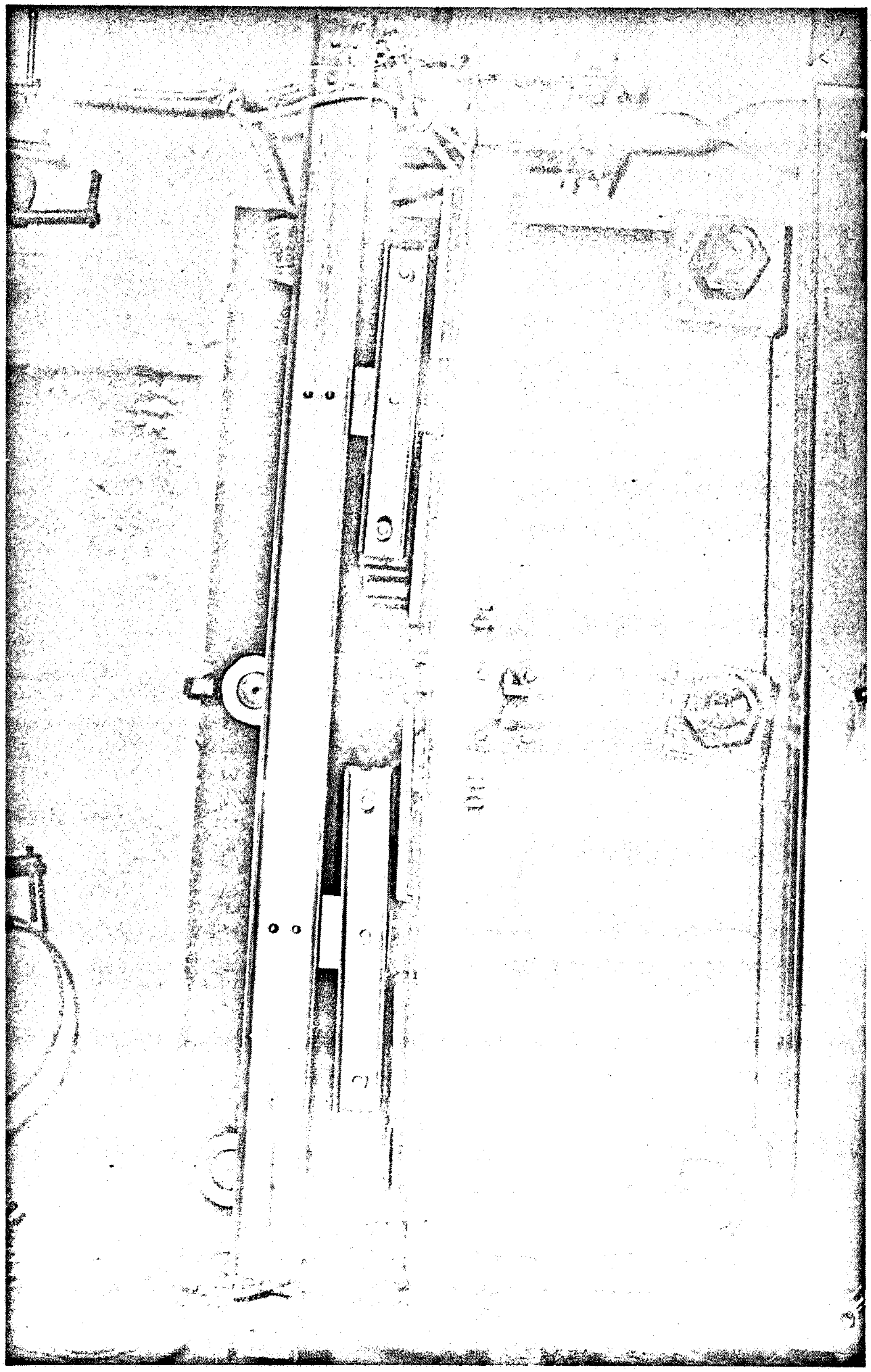

FIGURE 29.—737 PRODUCTION SPOILER UNDER 100% LIMIT LOAD

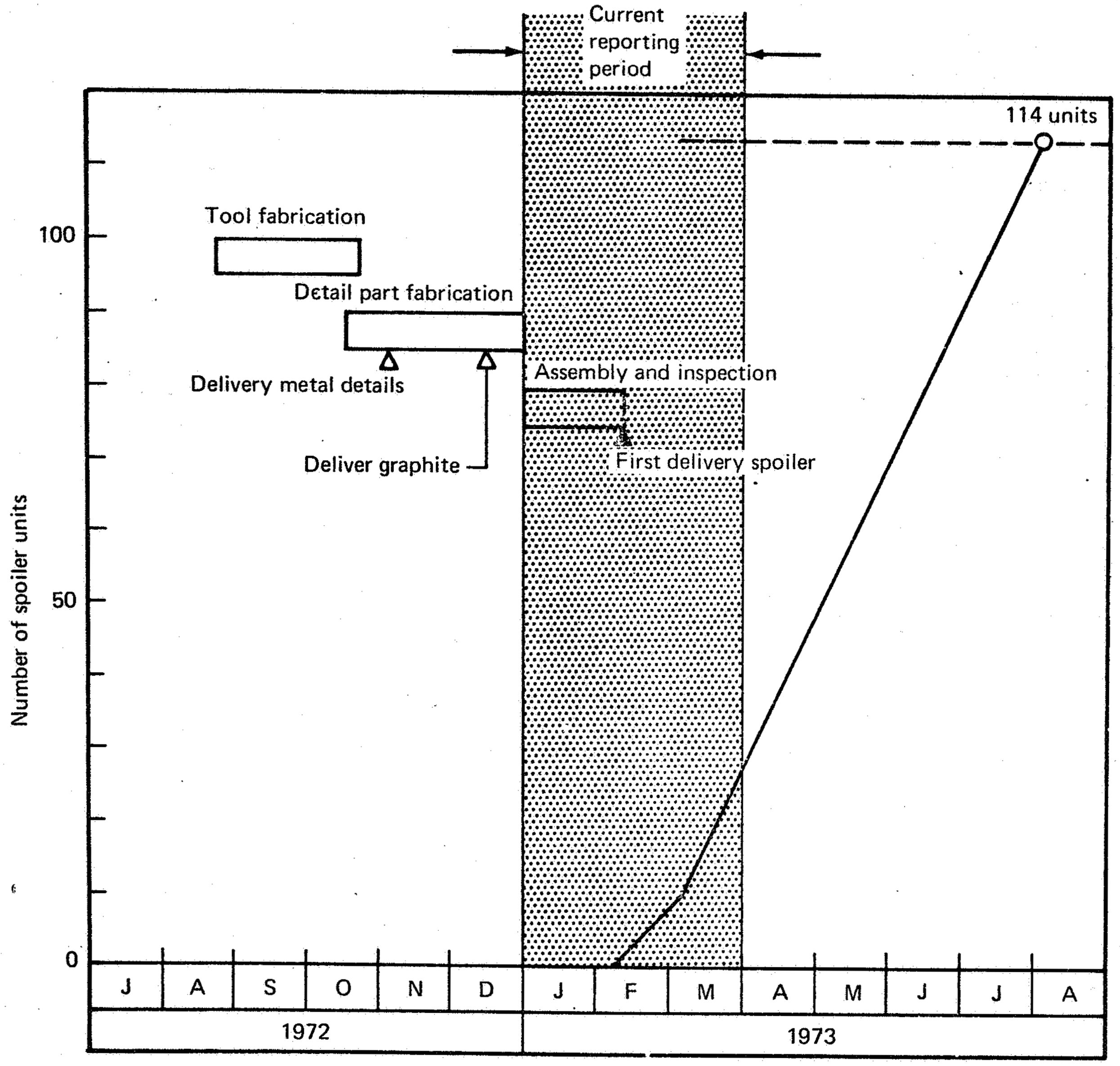

FIGURE 30.—SPOILER PRODUCTION SCHEDULE

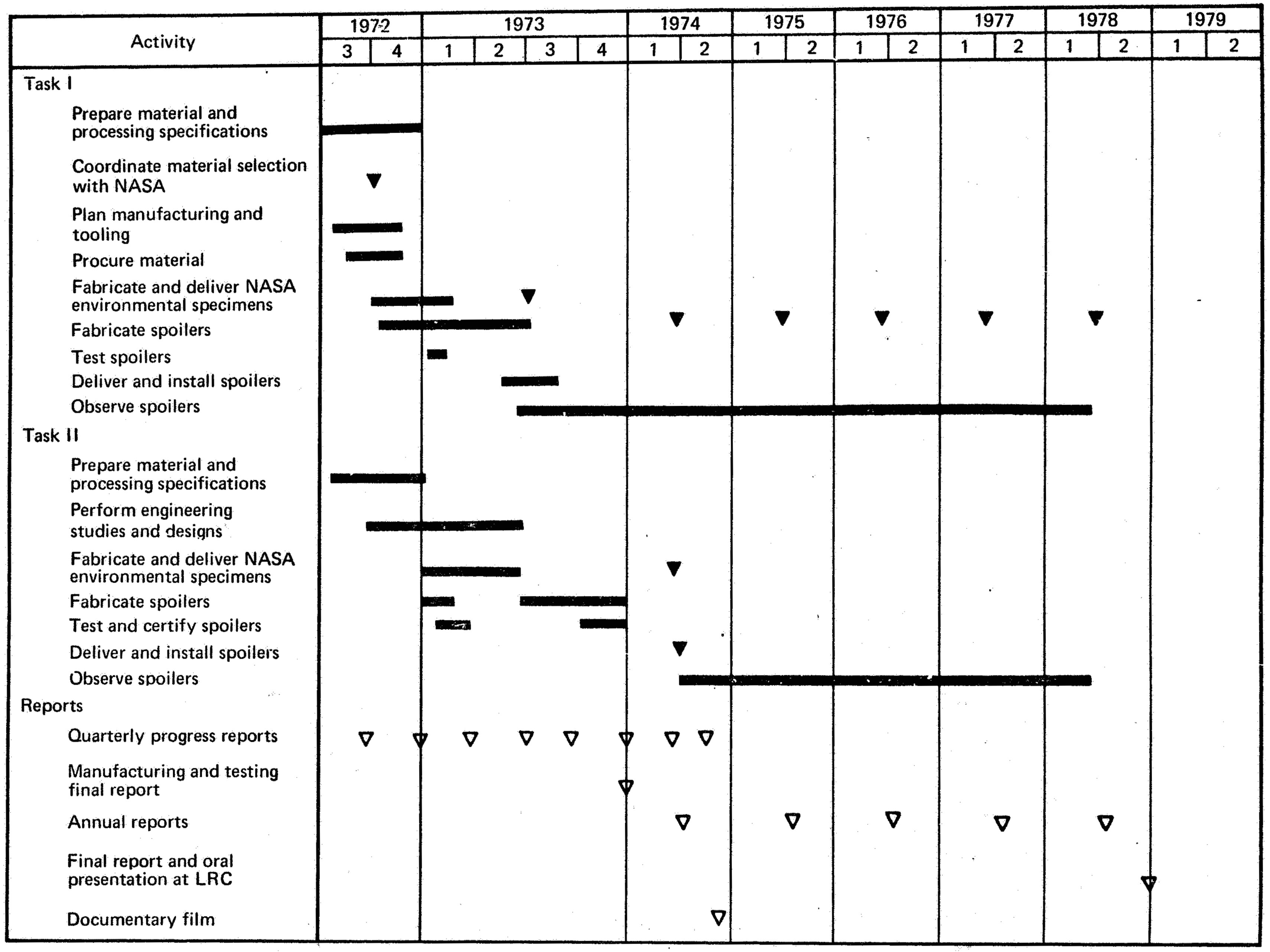

FIGURE 31.—PROGRAM SCHEDULE